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**COMPUTER-ASSISTED INSTRUCTION IN THE
CONTEXT OF THE ADVANCED INSTRUCTIONAL SYSTEM:
MATERIALS DEVELOPMENT PROCEDURES AND
SYSTEM EVALUATION**

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March 1980

Final Report

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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report details the second of a two part project to design, develop, implement, and evaluate an authoring system which would provide a basis for the cost effective production of computer-assisted instruction (CAI) materials. It addresses the definition of a procedural model for CAI development, development of a CAI Authoring Procedures Handbook, and evaluation of the complete authoring system. The procedural model consists of six major components: selection of target content, development of CAI materials, formative evaluation, definition and evaluation of student assignment rules, summative evaluation, and on-going evaluation. The Authoring Procedures Handbook describes the authoring procedures model and provides detailed instruction on use of the software tools. Evaluation of the system documents a substantial reduction in materials development time over that of conventional			

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approaches. Additionally, the materials developed reduced average: lesson and objective failure rates, first attempt study time, lesson and objective failure rates, first attempt study time, lesson time to criterion, end-of-block objective failure rates, and end-of-block test objective failure rates as compared to non-CAI approaches.

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SUMMARY

Objective

The overall objective of this project was to design, develop, implement, and evaluate an authoring system which would provide a basis for cost effective production (authoring) of computer-assisted instruction (CAI) materials for use in the context of computer-managed Air Force technical training. The specific target application was the Advanced Instructional System (AIS) located at Lowry AFB and the procedures and software developed were to be integrated into this system. The project work was conducted through two parallel efforts. The first of these two efforts addressed the development of computer software to facilitate authoring, presentation, and evaluation of CAI materials. The second effort, described here, concerned the definition of a practical procedural model for CAI lesson materials production, development of a CAI Authoring Procedures Handbook, and evaluation of the complete authoring system.

Approach

Design activities began with analysis of the probable functions of CAI within the AIS, review of prior approaches to supporting CAI materials development, examination of previous military CAI development experiences, analysis of the characteristics (training, prior experience, and work environment) of the Air Training Command (ATC) personnel who would be developing CAI materials, and re-examination of the available AIS software. A major conclusion resulting from these analyses was that there are a number of factors in the military technical training environment which are incompatible with the typical approach to CAI production and that prior attempts to utilize CAI in this environment had not taken these factors into sufficient consideration. It was decided, therefore, that it was preferable to adapt the authoring system to the existing environment rather than expect the environment to change to meet the requirements of the system, even when this approach limited the sophistication of the CAI materials which could be produced.

The most comprehensive component of the authoring system is the procedural model for CAI development. This model assumes the presence of non-CAI instructional materials which, for one reason or another, have been found to be inadequate. It begins by defining criteria for selecting specific lessons for CAI development. The next major component is an ISD-type evaluation of the selected lessons and their evaluation instruments in which any deficiencies in content or tests are corrected. Next, a general instructional strategy and an individualization strategy, consistent with the lesson content and student population, are defined. Materials development itself is largely structured by the Authoring Editor, to be described later. Following certain required actions, such as stating objectives, the author inputs text, diagrams, and embedded and objective level test questions and defines performance-contingent

branching logic. The use of appropriate response feedback and prompts (hints) is emphasized. Following review by other subject matter experts, one-on-one student tryouts are conducted and appropriate revisions made. Materials are then implemented in the classroom for formative evaluation. Standard data analysis reports are used to detect specific errors and appropriate revisions are made. On the basis of formative evaluation data and past experience with the main-line materials, a student assignment selection rule is defined and implemented. The effectiveness of this rule is contrasted with random assignment and revised as necessary. Finally, the overall effectiveness of the CAI materials and assignment rule are periodically monitored and revisions made as necessary.

The details of the software portion of the system have been reported elsewhere and are only summarized here. Briefly, the software consists of the following: The Authoring Editor, which allows authors to define CAI content and strategy without knowledge of a programming language; a set of general purpose CAI presentation programs containing automatic data collection routines; a family of print routines for listing CAI lesson content and branching strategy; and a set of data analysis reports tailored to the requirements of formative evaluation.

The AIS CAI Authoring Procedures Handbook describes each step in the authoring procedures model and provides detailed instruction on the use of the Editor. The manual is maintained on-line and, hence, is dynamic in nature in that changes in documentation of the authoring process can be made and distributed in near real-time fashion. Up-to-date versions of the manual can be printed and distributed as required.

Evaluation Procedures and Results

The complete authoring system was evaluated through (a) contractor development of CAI materials for six lessons, two block-review lessons, and two block-remediation lessons in the AIS Weapons Mechanic course, (b) implementation and evaluation of the instructional effectiveness of these materials, and (c) training a small number of ATC personnel in CAI authoring.

The CAI materials development process followed the steps outlined by the procedural model and employed the Authoring Editor. None of the three members of the contractor's authoring team had prior CAI experience; although all were experienced technical training authors. Approximately 2200 work hours were required for development of the six first-pass modules. These modules accounted for a total of approximately 25 Plan of Instruction (POI) hours and resulted in an average student contact time of 18.7 hours. Thus, development required an average of 88 man hours per POI hour and 118 man hours per student contact hour. This compares very favorably with the figures of 222 and 246 work hours per contact hour reported by other researchers for military technical training CAI.

The instructional effectiveness of the CAI modules produced was evaluated by contrasting them with conventional materials which they replaced. The six first-pass modules (a) reduced average lesson failure rates from 23% to 6%, (b) reduced average lesson objective failure rates from 19% to 2%, (c) reduced average first-attempt study time by 4.9%, (d) reduced average lesson time to criterion by 11.2%, and (e) reduced the average end-of-block test objective failure rate from 16% to 10%. The two block review modules reduced the average end-of-block test objective failure rate from 15% to 11%. The CAI block remediation modules were not evaluated due to the small number of block test failures during the evaluation period.

Three ATC instructors were trained in use of the authoring system during 15 one-half day sessions. None of the trainees were computer programmers or had any prior CAI development experience. There was no formal training after the first session. Rather, each trainee was given a copy of the Authoring Procedures Handbook and instructed to use the authoring system to develop a CAI module approximately one student contact hour in length. Contractor personnel were available to answer questions and review the trainee's work. At the end of the training period, each had developed a module through the stage of revision following single student tryouts. The author trainees asked relatively few questions and the modules produced were of generally good quality and capitalized on the capabilities of CAI. The trainees were quite satisfied with the authoring system and all expressed interest in implementing CAI in their courses.

Conclusions

The approach taken to facilitating CAI development appears very promising. Experience to date has demonstrated that effective CAI can be produced by non-programmers at a very reasonable cost, comparable to the effort required to produce paper-and-pencil materials. ATC personnel learned to use the authoring system and produced CAI materials within a very short period of time. These trainees expressed highly favorable attitudes about the approach and found no faults with the system.

The report concludes with a number of recommendations concerning further development and use of the CAI authoring system. Proposed improvements to the system include a dialog for detailed author definition of response processing rules for anticipated responses to constructed response questions, a capability for author-generation of graphic displays, additions to the Handbook addressing individualization strategies, and development of a CAI module for author training based on the Handbook. Given the current capabilities of the authoring system, more extensive use of CAI is encouraged for the current AIS courses, and it is suggested that further applications be sought in other resident courses at Lowry AFB and in the area of detached training. Finally, it is suggested that author training be made a part of the formal instructor training course.

I. INTRODUCTION

Computer-based instruction (CBI) has the potential of achieving significant savings in Air Force technical training related costs by reducing course lengths, administrative workloads, etc. A number of steps toward realizing this potential have already been taken, e.g., use of the PLATO computer-assisted instruction (CAI) system and Air Force development of the Advanced Instructional System (AIS) at Lowry Air Force Base.

The AIS, which provided the context for the work described here, was a large scale CBI system designed to improve the effectiveness and efficiency of Air Force technical training and to provide an operational research facility for assessing innovations in instructional technology. The system supported four technical training courses representative of the range of cognitive and performance skills required by enlisted Air Force personnel. The AIS utilized an instructional decision model employing state-of-the-art computer hardware, software, statistical methodologies, and instructional management and individualized assignments to alternative instructional materials.

The AIS was designed to support both CAI and computer-managed instruction (CMI). CMI can be defined as a situation in which the majority of the student's instructional activities are completed off-line. The computer's role is that of evaluator, diagnostician, prescriber, and manager of instructional events. In CAI, by contrast, all of the student's instructional activities are conducted on-line, at an interactive computer terminal. CMI can be characterized as being extensive, managing instruction for a large number of students throughout a large body of course content. CAI, on the other hand, is typically intensive, concentrating on detailed, highly interactive instruction for, generally, a limited segment of course content and a relatively small number of students. Extensive application of CAI has, to date, been restricted by the limited utility of short segments of individualized instruction embedded in a group-paced environment and by its high costs, in terms of both terminal costs and materials production.

The work reported here capitalized on the concept of CAI embedded in the context of CMI. Such an integrated system permits more efficient use of CAI since student pacing has been individualized. In addition, student performance on CAI lessons can be recorded directly by the CMI system and the extensive student performance records maintained as part of CMI can be readily accessed to provide truly individualized CAI when and where it is most needed.

Project Purpose

One of the major obstacles to widespread adoption of CAI has been its relatively high cost as compared to more conventional instructional media. Traditionally, the high costs of CAI have been attributable to

both the cost of the computer hardware delivery system (i.e., the required computing power and the need for an interactive terminal for each student) and the time and skill levels required for CAI materials production. Recent years have seen dramatic reductions in the cost of computer hardware, particularly with respect to interactive terminals with limited graphics capabilities. Thus, production costs have become a major factor in inhibiting the further use of CAI in military training.

There are a number of reasons why CAI production costs have remained high. With few exceptions, CAI authors have been required to define their materials and instructional strategies via a computer programming language. Typically, the work has required extensive and detailed effort. For the CAI produced to be effective, there has also been a requirement for relatively sophisticated instructional design and evaluation skills specific to interactive, individualized instruction. Due to these requirements, substantial training and experience have typically been necessary before CAI authors could become fully productive. The objective of this project, therefore, was to design, develop and evaluate an approach to CAI authoring which would allow novice authors to be immediately productive in CAI materials design, development, evaluation, and revision.

The software development portion of the project has been described in detail by Montgomery and Judd (1979) and is only summarized here. The purpose of the work described in this report was to define a practical procedural model for selecting promising applications for the CAI medium, developing materials for these applications, and evaluating their effectiveness; to develop a CAI Authoring Procedures Handbook; and to evaluate the effectiveness of the complete CAI authoring system in an operational environment.

Project Context: The AIS Environment

Each course supported by the AIS is divided into "blocks" of instruction which may require from 1 to 10 days to complete. Each block contains a number of instructional units or lessons, and most require a comprehensive end-of-block test. Within a block, lessons are arranged in a hierarchy based on their prerequisite relationships. A typical hierarchy resembles a set of parallel chains diverging and converging on certain pivotal lessons. A student may alternately work on lessons in two or more chains.

The basic unit of instruction is the lesson. Each lesson consists of one or more objectives, two or more parallel forms of a criterion referenced test, criteria defining mastery on the test, and typically, a self-test by which students can evaluate their understanding of the lesson before taking the criterion test.

A lesson's instruction is provided by one or more modules, each of

which teaches the complete lesson content. Where two or more modules are present, they represent alternative instructional treatments. Depending on the lesson content and the nature of the treatment, a module may be a programmed text, an elaborated technical order, an audio-visual presentation, or an interactive CAI session.

An AIS Student Scenario. A student's first experience with AIS is to complete a preassessment battery consisting of a number of scales which assess cognitive and affective factors considered to be predictive of a student's performance in the course. The student then requests his or her first assignment by submitting a Forward-Going Assignment request at a management terminal which consists of an optical scanner and medium speed printer. At this point, the student is enrolled in the course, but has not yet entered a block containing actual course content. The system then selects the block in which the student is to start work. Since the student has not yet completed any course work, only blocks which have no prerequisites are considered. If there is more than one such block, the one containing the fewest students relative to the desired number in that block is selected. The student is then assigned to an appropriate learning center and home carrel and to a specific lesson, module, and criterion test.

Lesson assignment decisions are made by a program called the Adaptive Model which consists of two major components--the Adapter and the Resource Allocator. The Adapter attempts to select, for each assignable lesson, the one module which is most appropriate for that student. This decision can be based on a variety of rules, e.g., select the module which the student is predicted to complete in the shortest time given that the student is also predicted to pass the criterion test. Each alternative module is given a weight indicating its relative preference. The Resource Allocator assigns preference weights to modules on the basis of minimizing the assignment's impact on the availability of instructional resources. Final lesson and module selection is based on a compromise between the two sets of preference weights. The form of the criterion test is selected at random.

Having received the first assignment printout (called a Student Status Report) at the management terminal, the student reports to the learning center instructor, obtains the instructional resources required for the assigned module, and begins work, normally at a home carrel.

After studying the lesson materials, the student completes a multiple-choice self-test and reviews the material pertaining to any questions answered incorrectly. The student then completes the lesson criterion test and submits the form to a management terminal. The resulting Student Status Report details the student's performance on the criterion test (percentage total score, items missed, objectives failed, and pass/fail decision) and the next assignment. If the test criterion was not met, the student is reassigned the same lesson and, if available, a different module. After restudying the lesson, the student is assigned

another form of the test. Otherwise, the lesson, module, and test selection procedures are repeated and the student is assigned a new lesson.

If the student assignment is a CAI module, there is only a slight variation in these procedures. That is, the function of the self-test is assumed by questions embedded in the CAI presentation, and the criterion test is administered on-line. Test results are submitted automatically to the CMI system, and the Student Status Report is displayed on the terminal. A printed copy of the report is also available from the management terminal.

When a student has completed all content lessons in the block, a Block Review lesson, if required, is assigned. Following review, the student is randomly assigned to one of the alternate forms of the block test. While lesson tests can be viewed as diagnostic tools, end-of-block tests serve a certification function. That is, since there is no end-of-course test, block test performance serves as the basis for certifying mastery of the objectives contained in the block. A student who does not meet the block test criterion is reassigned to the block in a status whereby assignments are made by the instructor rather than by the system. If the block decision is "Go," the block selection logic is repeated and the student is assigned to the next block of study. The student's continued progress through the course is essentially a repetition of these events.

II. AUTHORING SYSTEM DESIGN CONSIDERATIONS

Design of a cost-effective CAI component for the AIS began with an analysis of the AIS environment: the appropriate role of CAI within a CMI system supporting military technical training; the characteristics of the personnel who would be developing CAI materials; and the software tools currently available within the AIS. Lessons learned from prior approaches to CAI development were also considered.

The Role of CAI Within AIS

First it must be recognized that the prototype AIS is primarily a CMI system. This is not to imply, however, that the system was not designed to accommodate CAI. Rather, within the context of the AIS, CAI was seen as one of several possible media available for instructional purposes. Management and monitoring of the students' progress through a course, assignment to specific instructional treatments and evaluation of instructional effectiveness are all supported by the CMI component of the system.

Given the nature of the AIS form of CMI, defining the role of CAI within its structure was relatively straightforward. Recall that an AIS course is divided into blocks of instruction which conclude with certification tests. Blocks are divided into lessons and each lesson is supported by one or more modules, each of which addresses all of the lesson's objectives. When two or more modules are available for a lesson, they are treated as alternative instructional treatments for that lesson. The Adaptive Model assures that a student is not assigned a lesson until all prerequisites have been completed. Assignment of a specific module is also a CMI function. Thus, CAI was seen as providing one of two or more alternative instructional treatments for teaching a lesson, and as such, CAI materials were to be packaged and assigned as modules. Student terminals required for CAI were to be treated as instructional resources managed and assigned by the Adaptive Model.

It was assumed that if a student was assigned and completed a CAI module, it would be desirable that the lesson test also be administered on-line rather than via a management terminal interaction. While the AIS did support an on-line, computer-assisted testing (CAT) capability, it was designed primarily for block tests and was not totally suited for administration of lesson tests. Therefore, a lesson-level testing capability was to be incorporated into the CAI component.

The next major question concerned the types of applications for which these traditionally expensive modules would be most effective. While the use of CAI for normal first-pass instruction was one obvious answer, it was hypothesized that the branching capabilities and moment-to-moment control over student behavior afforded by CAI would be particularly useful for the functions of review and remediation.

As AIS courses are currently structured, nearly all blocks end with a review lesson which is assigned immediately prior to a block test. No specific instructional modules had been developed to support these lessons. However, the CMI system provides a "Block Report" which lists objectives which the student failed on the first attempt at lessons. It was intended that students would use this list to review those block objectives on which they had encountered problems. Instructional activities during this period are determined primarily by the student and the instructor. Student performance data from these activities indicate that this time was often not used effectively. CAI was seen as an excellent way of remedying this situation.

A procedure was envisioned in which, when a student was assigned to a block review, the Adaptive Model would assess the student's prior performance in the block and, if performance was found to be marginal, assign a CAI module. The CAI module would, in turn, determine the specific objectives on which the student had encountered problems, review the student on these objectives, administer and evaluate objective-level diagnostic tests, provide further remediation as necessary, and issue a Student Status Report suggesting further review or assignment to the block test as appropriate.

Block remediation presented a similar situation. A student who fails a block test is placed in a "block remediation" mode. In this mode, the system accepts tests input by the student or instructor, but the system does not make specific assignments. This role is delegated to the instructor. To guide the instructor in making appropriate assignments, the objectives which the student failed on the block test are listed on the Student Status Report printed when the block test was scored. Again, student performance data suggested that this remedial time could be employed more effectively.

CAI block remediation modules were envisioned which would differ only slightly from the review module. Student assignments to CAI remediation would be made by the instructor and selection of specific objectives for remediation would be based on the student's block test performance rather than on performance on the block.

Although block review and remediation were seen as two prime targets for CAI, it was assumed that CAI would also be used for alternative modules for first pass instruction. While CAI might occasionally be used for the first module developed for a lesson, it was expected that it would more often be used as an alternative treatment designed to remedy specific problems detected in an existing module. For example, some students could benefit from interactive elaboration of concepts instead of simply being presented expository remarks which might only confuse them. Or, it could be used to present frequent questions to assess levels of understanding and thereby effect more individualized instruction through appropriate branching.

Anticipated Characteristics of CAI Development Personnel

In considering the characteristics of the personnel who would be developing CAI modules, it was first thought that a team approach, such as advocated by Bunderson (1973), would be appropriate. Such an approach would specify differing roles for (at least) subject matter experts, instructional technologists, and program coders. However, further analysis of the military technical training environment strongly suggested that, while desirable, the team approach was very likely to encounter serious problems in practice.

During the 5 years that the AIS had been operational, there had been repeated efforts to define specific roles for specialists who are so important to effective operation of CMI (e.g., materials writers, evaluators, and data base managers). To date, these efforts have had limited success. It was concluded, therefore, that the CAI authoring system should be structured so as to allow a team approach to CAI development, but should not be dependent on it.

For the immediate future, at least, it was reasonable to expect that the personnel who would be developing, evaluating and revising CAI materials would be classroom instructors. It was assumed that such authors would typically be expert in their subject matter area, would have limited training or experience in instructional systems design, would have no prior exposure to CAI and would have no computer programming experience. Additional pertinent characteristics included a relatively high turnover rate for military instructors, little or no opportunity for formal training, and limited, fragmented periods of availability (e.g., 60 to 90 minutes following a normal instructional day).

An obvious problem raised by this profile of the typical CAI author is the lack of computer programming expertise and the strong indication that attempting to train relatively transient authors to program would not be practical. Therefore, an approach was sought which would eliminate, or at least substantially reduce, the need for computer programming on the part of the author.

A second major implication of the analysis of authoring-personnel characteristics was a need for procedures which would structure the authoring task. At the same time, it was recognized that excessive structuring could be perceived as being undesirable, even offensive, and could consequently, detract from the authors' motivation. It was reasoned that they would be more amenable to task structuring once CAI was established and authoring problems had been recognized. It was concluded that the authoring system should include a set of general procedures which at least defined and outlined each critical step in the development process.

The high turnover rate of military personnel had the obvious

implication that the authoring system and procedures should be such that a novice author could quickly be brought to a productive level of proficiency. Further, it was apparent that it would often be necessary for new authors to complete CAI modules that had been designed and partially developed by others.

Coupled with the high turnover rate was the expectation that there would be little or no opportunity for formal training in either the design or the mechanics of authoring CAI materials. It was assumed that most training would have to be conducted on the job. Thus, self-instructional methods, with some minimal assistance from experienced authors, appeared necessary.

Finally, experience gained from various DOD projects indicates that management of instructional materials development is an area that has been generally problem prone because of its complex, unstructured nature. Few effective management procedures have been successfully implemented. Consequently, little monitoring of individual authors during materials development has been possible, especially with respect to productivity and quality control. Thus, there was a need for procedures and software tools which would facilitate management of the development process. As was the case for structuring the authoring task itself, it was necessary that these management tools be fairly open-ended and allow for further development as management procedures evolved. Review of completed materials by other subject matter experts was known to be particularly time consuming and fraught with problems of conflicting interests and personal opinions. A procedural model and software tools which would structure and accelerate the review stage were considered especially important.

CAI materials evaluation had potential for problems which were at least equal in severity to those of authoring per se. It was assumed that the CAI authors would have primary responsibility for formative evaluation of their own materials but would have little, if any, prior evaluation experience. As a result, there was a need to structure student performance data collection, retrieval and reporting. In this case, it was thought that there would be little negative reaction to over-structuring. Thus, it was desirable that these steps in the procedural model be quite explicit and that the data collection process be almost totally predetermined to result in standard reports tailored for formative evaluation.

Software Considerations

Two aspects of the AIS software which strongly influenced authoring system design decisions were availability of the CAMIL programming language and past experience with the use of interactive data base editors.

CAMIL (Computer Assisted/Managed Instructional Language) (Pflasterer, 1978) is a higher level, general purpose programming language developed as an integral part of the AIS. The language is oriented toward support of both CAI and CMI applications and was designed to be used by personnel with a wide range of experience.

While the AIS CMI functions are supported by CAMIL software, day-to-day operation of the CMI system is controlled through a set of data base editors. The intent of these editors is to allow course personnel with no programming skills to define the characteristics of their courses and establish the rules by which student assignments are made. With this approach, software changes are only required when the basic operating philosophy of the system is altered. Normal operational changes in course content and configuration, resource inventories, and student assignment selection rules are made by changing the course data base via the interactive data base editors.

Operational experience with this approach has been quite positive. Relatively few software changes have been necessary to meet the system's evolving instructional requirements. Despite the complexity of the data base, course personnel are able to use the editors to institute data base changes appropriate to their needs. This is not to say that the use of the editors is totally straightforward. The data base and the interactions among its components are complex. While all of the editors prompt the user's inputs to some degree, extensive prompting was sometimes sacrificed in favor of efficiency. In retrospect, this trade-off was sometimes inappropriate.

In general, the interactive editor approach was thought to hold considerable promise for facilitating at least some aspects of the CAI development process. It was also recognized that where such an approach was adopted, it would be desirable to provide extensive prompting.

Prior Approaches to the Authoring Problem

A growing recognition of the problems associated with CAI development has resulted in a substantial literature addressing these problems and proposing alternative solutions. The following sections provide a brief introduction to the concept of CAI authoring systems and a summary of two Air Force experiences in CAI development.

Authoring System Considerations and Criteria. Zinn (1974) lists four criteria for assessing the effectiveness and utility of CAI authoring languages: reliability; efficiency; flexibility; and convenience. Many of these same criteria can also be applied to the more general concept of an authoring system.

Under reliability, Zinn includes automatic recovery for both author and student following computer failure, limiting the loss of authored material and limiting the domain of author errors, i.e., an error in one

part of a program should not impact other parts of the program or other programs. Efficiency refers to both the time required for authoring and the computer time required to translate author language statements into executable code. Flexibility considerations include access to a variety of devices and alternative modes of execution or conventions and the capability of adding new operators, statements, and subroutines.

Author convenience is treated as a major consideration. Zinn suggests that the language (or the programming component of an authoring system) should have a minimum of redundancy and irrelevant syntax, e.g., the program listing should be no more complex than the author's actual task. There should be provisions for alternative authoring styles, e.g., while many authors indicate a preference for interactive entry, others prefer to work with paper forms which remind the author of system capabilities and requirements. With respect to revising an existing program, Zinn notes the advantages of on-line editing and suggests that the system should provide access to the original file, use straightforward notation for determining changes to be made, and confirm that changes were accomplished. In testing a program, the author should be able to begin execution at any point and trace through the program using labels as indicators of location. The language notation should help a reviewer understand the intent of the instructional content and strategy. Finally, access to system capabilities should increase with experience.

Kaplow (1975) states that in order to maximize assistance to the author, it is not sufficient to simply add authoring aids to a programming language. Rather, the total software component of the CAI system must be organized around this goal. He then describes what he considers to be the basic features of such a system.

First, the system should provide a structured format to help authors organize their concepts. The current working unit should always be identified and the author's statements should refer only to this unit. The system design should make it explicit that a CAI program is a collection of information organized so as to be amenable to understanding. The computer itself should automatically perform many programming functions such as checking structural completeness and finding cross reference errors. Finally, the system should not require that a program be complete before it can be tried out.

In his subsequent discussion, Kaplow makes a number of additional critical points. The system should be tolerant of user errors and point out errors at the time they are made. The details of presentation should be defined on the basis of the implication of the author's instructions rather than requiring the author to specify actions in detail. The system should help the author keep track of the interrelationships between the various parts. The fact that it is often easier to write a new program rather than to modify an existing one is particularly unfortunate considering the opportunity, even requirement, for CAI revisions based on student performance. Since the source of

this problem is usually one programmer's difficulty in understanding the structure and logic used by another, the system should place particular emphasis on the ease with which one can use existing material.

Example Authoring Systems. The earliest CAI programs were written in the available general purpose computer languages. Although this is still a popular approach (e.g., the extensive use of BASIC), there was early recognition that authoring could be facilitated by languages tailored to the particular requirements of CAI. Consequently, there was a proliferation of CAI authoring languages--at least 30 by 1973. The last decade has also seen experimentation with various author entry systems--approaches which are relatively independent of a specific language. The following paragraphs briefly describe an example of a modern CAI authoring system (PLATO IV) and some approaches to developing

The PLATO (Programmed Logic for Training Operations) IV system relies heavily on the power of the TUTOR language (Sherwood, 1974). The system provides for interactive entry, easy trial and revision of code, and is quite responsive to authors' needs in terms of display time, compilation time, and diagnostics. The author's task is facilitated by a number of aids such as on-line access to reference materials, simple program routines, and files of current documentation and comments. To a large extent, the PLATO approach to authoring is based on the model of an author who is a versatile professor: an expert in the subject matter; an experienced teacher with sound but innovative ideas about instructional presentation; and a capable programmer. In other environments, where the authors have been less experienced, less skilled, and/or less motivated, the approach has not been proven to be as satisfactory.

Dowsey (1974) describes five categories of approaches to building easy author-entry systems: (a) separation of logic and content; (b) avoidance of any authoring language; (c) use of lesson planning and formatting guides; (d) conversational materials generation; and (e) macro systems. The approaches in each category tend to build on the concepts of the prior categories.

Almost all of these approaches employ the tactic of separating instructional content from program logic. This divides the authoring task in a way that is particularly amenable to a team approach. Dowsey notes that, to be effective, such separation requires similarity of structure between the two components.

The no-author language approach not only separates content and logic but does not require the author to define the logic. Only the content is specified, in the form of frames or problem categories. This is then acted upon by a lesson generation program which treats the content as data to produce instructional materials.

The use of lesson planning and formatting guides, while requiring the services of a coder, permits the author to communicate in English. Typically, the author defines the material to be presented, the questions, the expected answers, and the corresponding courses of action on a standard form which specifies the categories of information required. One of the more sophisticated examples of this approach is Dowsey's own COURSEMAKER, designed for use with the COURSEWRITER III language. It is based on use of a paper form which includes a presentation section containing the material to be displayed, a question section indicating the student response(s) expected, a decision section defining whether a branch is to be taken and, if so, the type of branch, and an analysis section containing response judging rules.

Conversational materials generation represents a quite different approach. The interactive system assists the author by eliciting the content and logical structure of the lesson through a natural language conversation. Paloian (1974) describes one example of this approach. The author defines the program structure by entering a sequence of action verbs. The system checks the accuracy of the sequence, and if it is correct, prompts the author to supply the text, anticipated responses, counter names, etc.

Dowsey sees the use of macro routines as potentially being the most powerful approach. In using such a system, the author retrieves a program sequence of code and specifies arguments which complete the routine. One characteristic of this approach is that it imposes a definite structure on the material produced. TICCIT (Stetton, Volk, & Bunderson, 1973) is probably the best known example of a macro system. TICCIT employs a single instructional strategy, oriented toward concept learning, which assumes learner control over sequence. The strategy specifies how the subject matter should be structured (e.g., rules, examples, practice items) and even suggests the appropriate number of items in each category. Thus, most of the author's task consists of molding the contents to fit the strategy. Planning guides are used to format the content and define presentation tactics by selecting among available options. A macro processor then converts this information (content, content format, and strategy option) into computer language.

One other macro-oriented approach that deserves mention is the use of Monoforms (Schulz, 1975), developed for use by military authors on PLATO IV. The Monoform macros, written in TUTOR, were intended to facilitate preparation of frequently used question types by providing a question format and eliminating the need for the author to understand TUTOR. A total of nine macros were developed for multiple choice, constructed response, and matching questions. Within each question type, the Monoforms differ with respect to variation in format; type of feedback, and for multiple choice questions, order of alternative presentation. There are also a number of options within each Monoform. The author copies the desired Monoform and follows the instructions (supplied in the form of program comments) to supply the question content and

tailor the TUTOR commands to his or her specific requirements. Schulz reports that the use of Monoforms reduced the 2- to 6-hour question development time to only 10 to 15 minutes.

Air Force CAI Authoring Experience. Himwich (1977) reports a comparison of TICCIT and PLATO authoring efficiency conducted at Maxwell AFB. The results of the comparison were inconclusive with little difference found between the two approaches. In the production of 32 contact hours of CAI, the PLATO team required an average of 222 work hours per contact hour while the TICCIT team required 246. Of greater interest is Himwich's description of the procedures followed and the problems encountered, particularly by the PLATO team. The training provided for PLATO team members consisted of an intensive 2-week session and subsequent continuous consulting support by the PLATO staff. TICCIT team training began with 7 weeks of familiarization followed, some months later, by 3 weeks of intensive training. In both cases, the training required appears excessive. Further, Himwich reports that, in some instances, authors did not capitalize on PLATO's flexibility with respect to instructional strategies and, consequently, did not demonstrate the system's full capabilities.

Dallman, DeLeo, Main, and Gillman (1977) provide a comprehensive description of an evaluation of the use of PLATO IV for Air Force technical training. At the beginning of the test, conducted at Chanute AFB, the typical PLATO authoring model was adopted with each author acting independently. Learning TUTOR was found to occupy a major portion of the author's time. Authors had varying styles and quality control standards, and as a result, the curriculum was fragmented with little continuity between lessons. Dallman et al. concluded that a basic flaw in this approach was the unrealistic assumption that the materials' authors were experts in both subject matter and instructional practices.

A team approach was subsequently adopted in which the team consisted of an author, subject matter expert, instructional programmer, and coder. Although this was a distinct improvement over the prior approach, a number of problems were still encountered. No written procedures were defined, only informal understandings among team members. This resulted in time-consuming coordination problems and inefficient use of team specialists. Administrative and management procedures were never well defined and there was a continuous need, never resolved, for better, more extensive author training.

A number of PLATO features were found to be quite useful. On-line data collection routines supplied by the PLATO staff and the capability for on-line text editing were both considered important. TUTOR was adequate for the site's needs with authors handling the simpler aspects of programming and coders required for only the more complex portions. Only a few of the more experienced authors, however, capitalized on PLATO's instructional flexibility. Almost all of the lessons produced employed the same simple tutorial model. The report authors suggest

that this approach was followed because the materials were easy to prepare, the subject matter was not that complex, and the student comprehension and retention requirements were low. Branching was used mainly for forced review and TUTOR's impressive response judging capability was seldom utilized. Only about 20 percent of the questions developed employed a constructed response format. Not only were constructed response questions more time consuming to program, students disliked them because of unfamiliarity with the typewriter keyboard and because of the requirement to recall and spell newly introduced terminology.

Dallman et al. drew a number of conclusions relevant to the current project. The team process was found more efficient and effective than individual authors. Authors did not exploit PLATO's full capabilities due to resource constraints, lack of CAI expertise, and inadequate training in instructional programming techniques. Finally, sophisticated CAI capabilities may not be necessary for the type of tasks and level of knowledge required for most phases of military technical training.

The types of problems encountered at Chanute and Maxwell appear typical for military technical training. Kimberlin (1977), describing the status of project ABACUS at Ft. Gordon, reports 5 to 6 month slips in the full implementation of CAI courses. The major problems encountered were reported to be changes in the Plans of Instruction during CAI development and the fact that the project was never assigned an adequate number of instructional programmers.

Design Conclusions

Since some aspects of the military training environment are less than ideal for efficient development of instructional materials, particularly CAI, it was concluded that it was best to adapt the authoring system to this environment. It was hoped that the authoring system itself would act as a mechanism which would encourage desirable changes within this training environment to be instituted.

A major consideration in the design of the AIS CAI authoring procedural model was the fact that the CAI to be developed was to serve as a component of a larger computer-based training system. Thus, it was concluded that the procedures should encompass the complete process by which CAI was to be integrated into the system. This would include selection of materials for CAI development, analysis of existing materials and evaluation instruments, definition and evaluation of rules for assigning students to CAI, and subsequent monitoring of CAI module performance, as well as the more conventional steps of materials development, evaluation, and revision.

In keeping with Kaplow's (1975) suggestion, the total software component was designed with the major goal of facilitating CAI materials development. Despite the fact that many features of CAMIL had been

designed expressly to support CAI, it was recognized that any approach that relied on an author/programmer had little chance of success. On the other hand, it was considered unlikely that personnel would be assigned to such a specialized function as CAI computer programming in sufficient numbers to adequately support many authors. This assessment suggested either a no-author-language approach or a macro system approach. The danger in these approaches was seen to be that they could be too rigid for the evolving computer-based technical training environment. Therefore, the design of the software component of the authoring system relied heavily on characteristics of the existing CAMIL system and capitalized on prior AIS experience with interactive data base editors.

The software component was seen as consisting of three major sections. The first, most visible, part was an authoring editor by means of which an author could define CAI content and branching logic. The format of the author's input was to be as similar as possible to what students would actually see. The editor was to automatically accomplish as much of the programming detail as feasible and to eliminate the need for authors to even be aware of the CAMIL language. The second part of the software component was to be a flexible "template" CAI presentation program which would support a class of CAI modules. Principles which had been used in developing the AIS Adaptive Model and its data base were employed to make this program as flexible as possible without undue complexity. The basic concept was that the content and branching logic defined via the editor were to be treated as data by the presentation program. Finally, to support evaluation activities, the presentation program was to contain student performance data collection routines, and a set of standard data analysis reports tailored to formative evaluation requirements were to be provided.

Difficulty in assuring adequate author training was accepted as a major problem. It was concluded that much, if not all, author training would have to be informal and take place on the job, implying a need for self-instructional materials. It had been intended that an Authoring Procedures Handbook would be provided. It was now recognized that this item would be critical and should address the full development process, starting with materials selection, as well as materials authoring per se. In addition, it was concluded that the authoring editor itself should structure the author's task and be as self-instructional as possible.

Since management of the CAI development process was also seen to be a major problem, it was concluded that the authoring system should contain tools which would facilitate tracking and monitoring the process. Capabilities which would expedite subject matter expert review were considered to be especially important. Wherever possible, it was thought that the software component should automatically capture and display information concerning development activities.

III. APPROACH

The overall approach taken to provide a CAI component within the AIS was to design and develop a CAI authoring system comprised of three major elements: a procedural model for selecting, authoring, and evaluating CAI materials; computer software to support the authoring process and CAI presentation; and a manual detailing the use of the model and software. The model and software were developed in parallel, with aspects of each influencing the other.

The model assumes the establishment of a team of material developers to accomplish course development, recognizing that this is seldom actually the case. The team should consist of material authors, subject matter specialists (SMSs), and educational technologists or psychologists. The team leader can be named from this group or can be one of the course's training or curricula officers. The team should be established prior to choosing course blocks for which materials are to be developed. The mix of team members will vary across courses as dictated by course needs, the team leader, and material complexity. Functional responsibility for specific steps within the procedural model should be assigned by the team leader.

A Procedural Model for Developing and Evaluating CAI Materials

Definition of an effective and efficient CAI authoring procedural model for the Air Force technical training environment began with an analysis of the characteristics of the instructional environment. This examined specifically the environment defined by the courses supported by the AIS, and the types of instructional problems for which CAI could provide solutions in this environment.

In general, the procedural model and support software were oriented toward production of a broad range of tutorial and drill and practice materials for both initial (first-pass) study and subsequent review and remediation. Once a general approach had been outlined, the authoring procedures were further defined and refined on the basis of AIS experience with CBI, and knowledge gained from review of other CBI systems and CAI authoring systems.

The procedural model, as derived, consists of six major components, each with a number of constituent steps. The components are selection of target content, CAI materials development, formative evaluation, definition and evaluation of student assignment rules, summative evaluation, and on-going evaluation. The full model is shown in Figure 1. The model's six component steps are described in the following paragraphs.

Selection of Target Content. The first component of the procedural model (see Figure 2) assumes the presence of a main track of non-CAI materials and defines criteria for selecting those materials for which alternate CAI modules are to be developed. The steps in this component

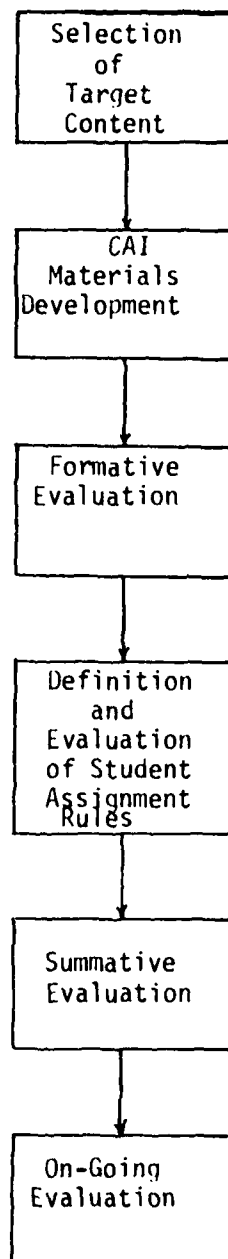


Figure 1. AIS CAI Procedural Model.

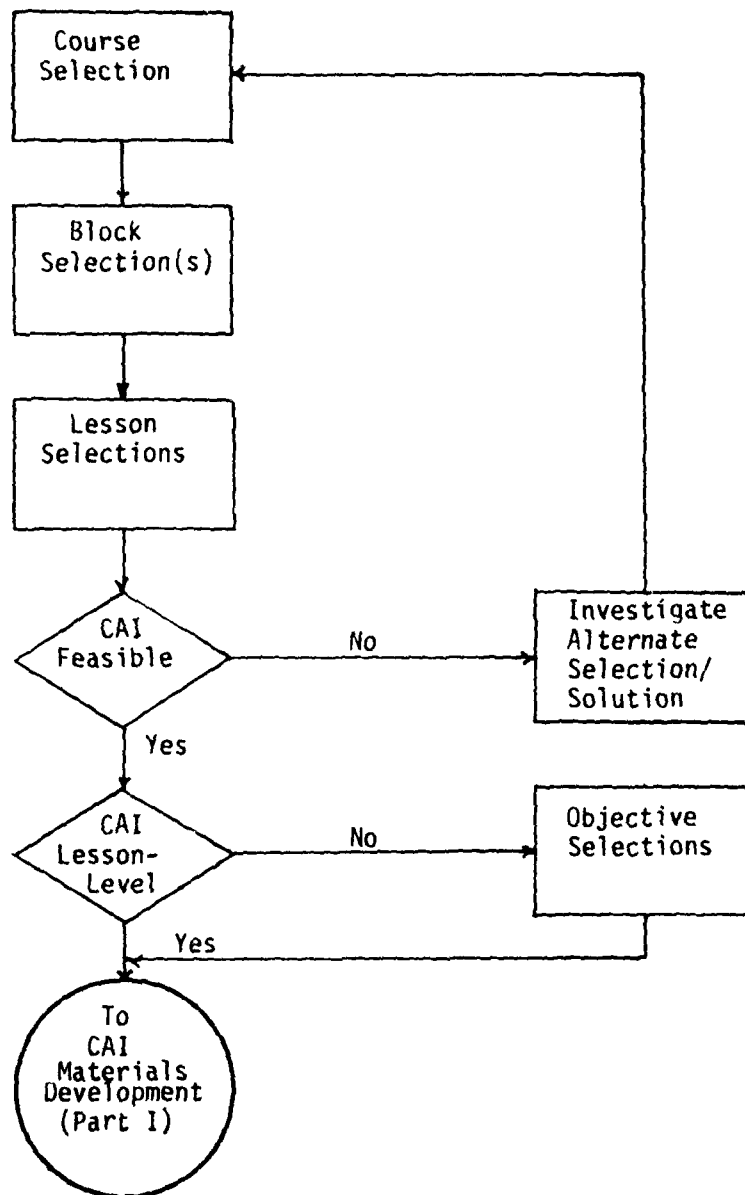


Figure 2. Selection of Target Content.

do not constitute a precise algorithm for content selection. Rather, the intent is to identify a number of factors which should be considered in determining target content selection; questions which repeatedly examine potential benefits in the light of the anticipated costs of these benefits. Few hard and fast rules can be defined, and value judgements play a major role in the decision process.

The first step in the content selection component is to select a course or courses where the use of CAI will be beneficial to the training process. This should be a school-level decision based on considerations such as student throughput, training cost per student, expected amounts of courseware change, levels and types of simulation required, student entry skills, courseware graphics requirements, instructor/student ratios, and types of training materials used.

The principal consideration must be to choose a course where CAI materials can improve motivation, and where the unique capabilities of CAI will provide needed individualization. A course might be selected if, for example, conventional materials are resulting in relatively poor field performance and the cost of CAI is relatively small when compared to overall training costs. Alternatively, CAI hardware costs may be relatively unimportant if CAI is determined to be the only available method for replacing an inadequate module.

After selecting a course, the next step is to select a block or blocks of instruction for conversion to CAI. In this step, many of the factors considered in course selection apply, e.g., types of materials used, expected amounts of courseware change, costs of training aids and simulation devices, etc. Beyond these, however, two primary considerations are block test failure rates and time to complete the blocks, as well as the variability in these measures. If the failure rate on a block test is high, if variability of scores on a block test is high, or the time to complete a block is greater than expected, then the individualization and improved motivation that can be provided through CAI may be a cost-effective approach to improving training.

Having tentatively selected one or more blocks, specific lessons must be selected. Here, the selection considerations are lesson failure rates, variability of lesson mastery test scores, subsequent block test failures on the objectives included in the lessons, and average times and variability of times to complete the lessons. As with block selections, such factors as rate of change of materials and costs and types of training aids and simulation devices must also be considered.

With respect to variability, if lesson mastery test scores are highly variable with many students scoring well above the passing criterion (which is judged to be adequate), it may be that those students should be given more cursory explanations of some portions of the materials, thereby reducing training time. High variability in time to complete the materials may point to a subset of students who do not

understand portions of the materials. In this case, CAI might be used with provisions for diagnosing specific problems and individualizing the instruction to decrease training time.

When the three selection steps (course, block, and lesson) are completed, it must be determined if CAI is feasible for the tentative selections. Possible reasons for determining at this stage that CAI is not feasible include low student flow, necessity for graphics or simulations which are beyond the capabilities of the available authoring personnel, or too few lesson selections to justify hardware or development costs.

If CAI is feasible for the selected lessons, the next question is whether CAI material should be developed for first-pass attempts over all the objectives within the lesson or should cover only problem objectives. If the materials are to cover only problem objectives, then should they be used for review before a block test, or to prepare for a second attempt on a block test covering only the objectives failed? If materials are to be written for problem objectives, solely or in combination with first-pass lessons, the available data on objective failure rates on first-pass lessons and on first-attempt block tests must be examined.

With the final selection of lesson and objective materials made, the author is ready to begin the next component of the procedural model, CAI materials development.

CAI Materials Development. Development of CAI materials should begin with a careful analysis of instructional requirements as described in Steps 2 and 3 of the Air Force Instructional System Development (ISD) process (AFM 50-2, 1979). This will ensure that the finished materials avoid such problems as omitting necessary content, covering objectives incompletely or at an incorrect level, incorrect or inadequate emphasis on particular subjects or concepts, incomplete material supplements, poorly designed teaching strategies, and tests which do not address the objectives.

The steps in the CAI materials development component are shown in Figures 3a and 3b. Steps 1 and 2 involve evaluating the measurement tools and the content outlines, respectively, of the materials selected for CAI development. The content outline is essentially a listing of every teaching step of, and general information concerning, the material to be taught. This evaluation is conducted in order to determine that the outlines are complete and that the tests adequately address mastery of the materials. The course Specialty Training Standard (STS) specifies the required levels of student understanding and is the standard against which outlines and tests are evaluated.

In the first step, evaluating tests, it is important that first-pass (lesson) tests and retention (block) tests have face validity for the

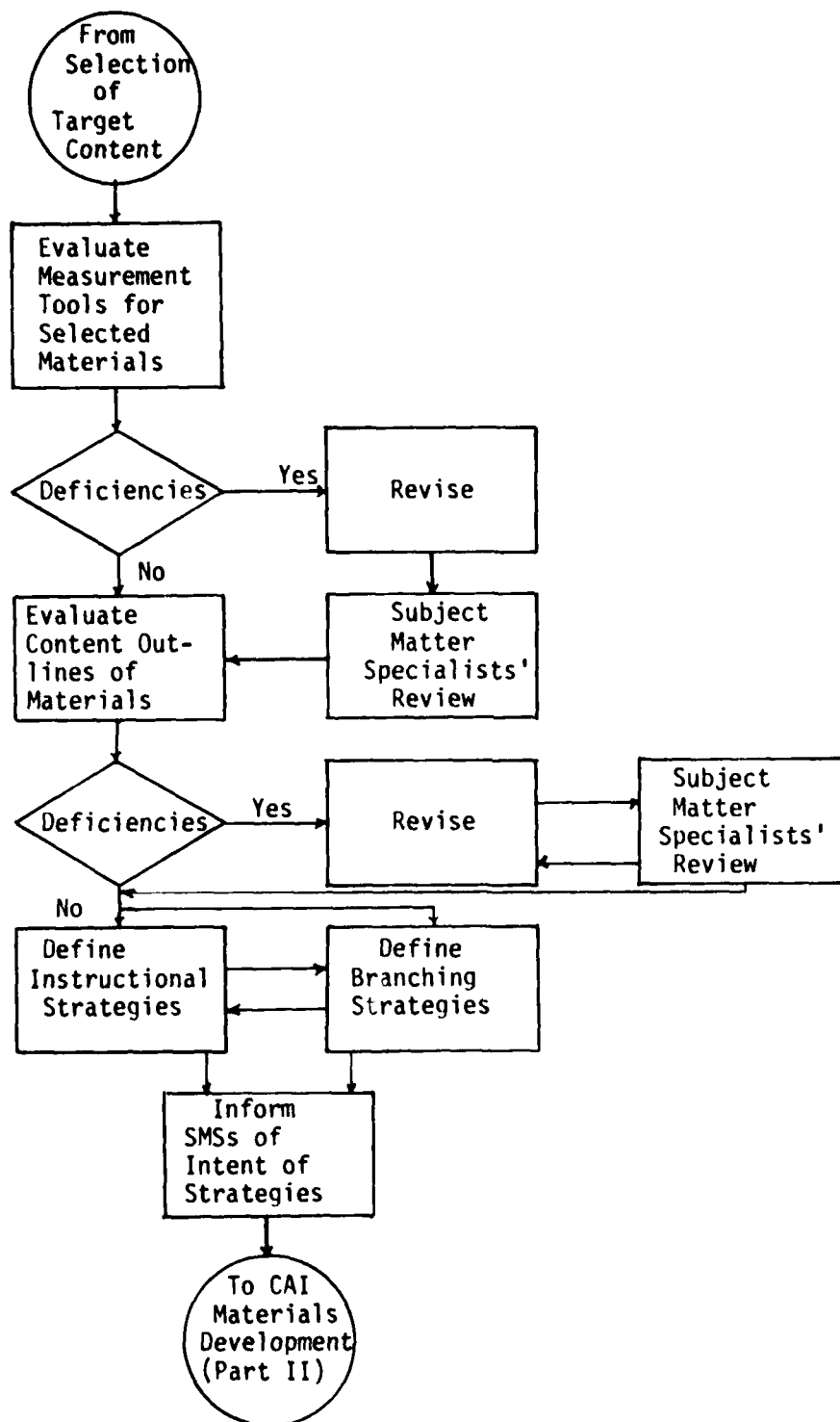


Figure 3a. CAI Materials Development (Part I).

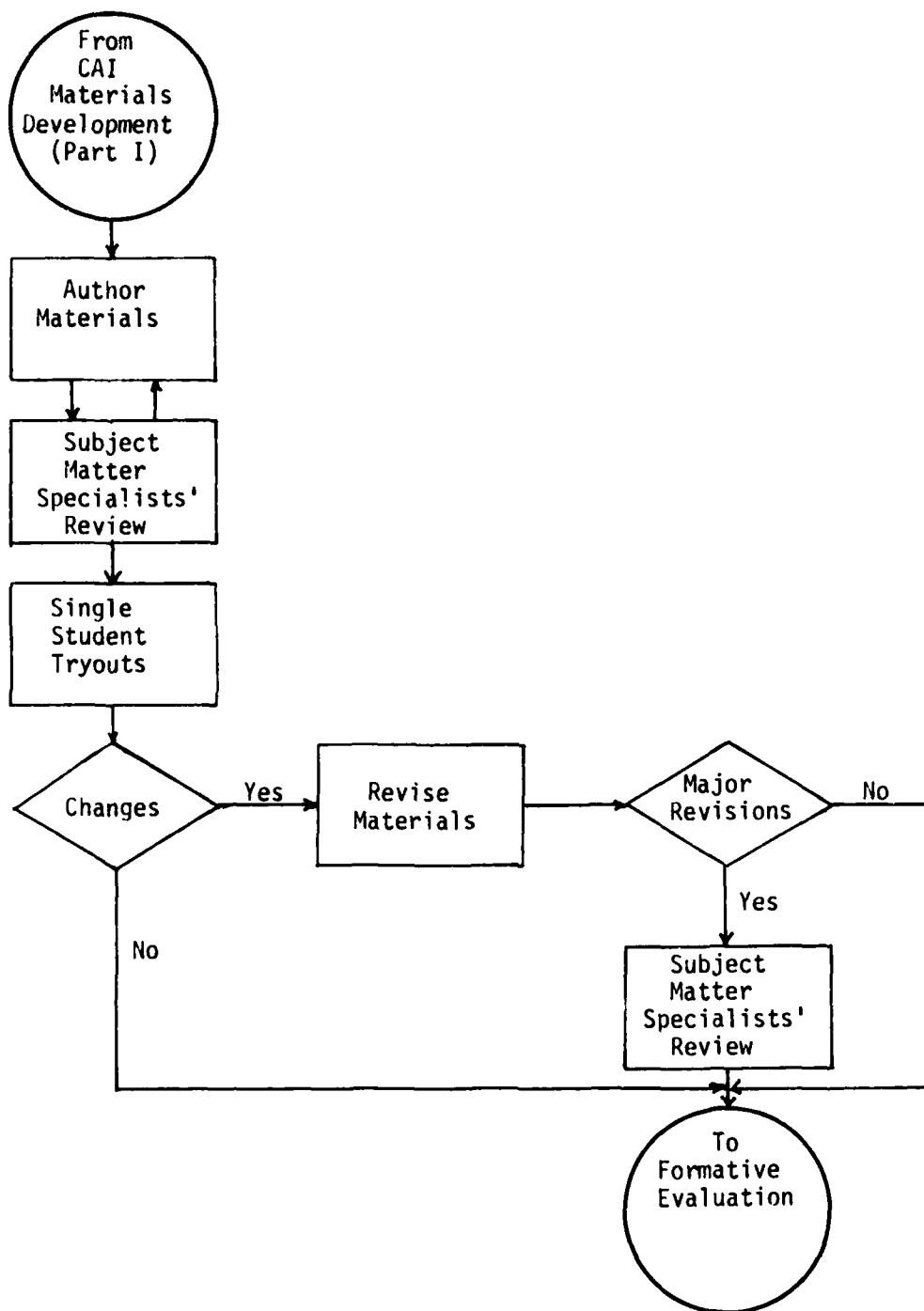


Figure 3b. CAI Materials Development (Part II).

objectives which they test and address the same subject matter at the same difficulty levels. It is also important that alternate versions of lesson and block tests cover the required subject matter at the appropriate difficulty levels. That is, lesson tests should first be evaluated and alternate versions should be cross-checked for equal difficulties. Block tests will then be evaluated and alternate versions cross-checked for consistent levels of difficulty. Last, lesson tests will be compared with the block tests to make certain that the block tests cover the same areas to the same level of difficulty using the same criteria for passing. The overall aim is to insure the level of mastery required by the STS.

In Step 2, evaluation of content outlines, the primary consideration is whether the content outline is consistent with the content area established by the learning objectives and their criterion tests. Since the content outline is the principal element which will guide the writing for materials, it must fully represent the intent of the STS to assure adequate field performance. Following Steps 1 and 2, any revisions must be reviewed by subject matter specialists to insure the technical accuracy of the content changes.

Unless these first two steps are successfully completed, all subsequent efforts may be jeopardized. For example, if the measurement instruments are such that they indicate good student performance but the field evaluations indicate inadequate graduates, CAI development work will be largely wasted.

Once it has been determined that the measurement instruments and lesson content outlines are valid and complete, materials development can begin with the definition of the instructional techniques to be employed. This involves determination of both instructional and individualization strategies. Typically, the two steps would be conducted in parallel since the approach taken in either one could influence the other.

Definition of instructional strategy includes determining the order in which various objectives and components of objectives should be taught and the level of mastery to be demonstrated on each component before the student is allowed to proceed. It should be noted that monitoring the student's performance on a step-by-step basis is much more feasible with CAI than with other self-instructional media. Although no one approach is specified, the model does advocate that the instructional strategy employed be based on a behavior classification scheme such as that proposed by Gagne (1970).

Individualization strategy concerns involve the methods to be used in matching the moment-to-moment instructional events to the student's current level of knowledge. For example, is pretesting appropriate or should emphasis be placed on posttesting and review of troublesome concepts? What is the appropriate frequency of embedded questions? Should

prerequisite concepts be tested? Does the subject matter and the anticipated level of students' prior knowledge lend itself to the use of learner control? An individualization strategy should be defined for each objective, considering the routes which students should take through the materials, based on responses to carefully selected and located questions. With a carefully designed pattern of branching for a lesson, it is possible that no two students will see exactly the same combination of materials, questions, feedback, and prompts.

After instructional and individualization strategies have been defined, SMSs should review the strategies. In this way, the personnel developing the strategies (e.g., educational technologists) can be certain that there is no inherent illogic in their teaching plans which might, for example, clash with classroom procedures or field duties.

After the foregoing analysis and design steps have been completed, the actual materials authoring can begin. If the preceding steps have been performed well and properly documented, the author need only be an SMS with some teaching experience--that is, particular instructional design skills are required for the subsequent steps.

The CAI authoring itself is done via the CAI Authoring Editor (developed during this project and described in the next section, Software Elements of the CAI Authoring System). Briefly, the Editor structures the authoring process and leads the author, step by step, through this process via an English language dialogue. Even if an author is an SMS, developed materials should be reviewed by peers. When the review process has been completed and the author and instructional strategist are satisfied with the quality of the product, single-student tryouts of the materials begin.

Within the procedural model, single student tryouts are subsumed under the development phase rather than being part of formative evaluation. This is because the purpose of the tryouts is not so much directed at evaluating the instructional effectiveness of the materials as it is at locating errors of content and logic which were overlooked by the authoring team. Typically, the number of students run would not be sufficient to answer questions concerning instructional effectiveness. Such single student tryouts do provide an avenue by which the author can learn if the materials are easily understood by their intended audience. They provide answers to questions such as the following. Is wording clear? Is order of progression correct? Are directions to the student clear enough to be followed? Are there inconsistencies between concepts and their examples? Is the lesson too long to hold the student's attention? Single-student tryouts should generally be run with several (8 to 12) students, but the number will vary with the number of errors found early in the tryouts and the extent of the branching in the module. If many errors are found with, for example, the first two or three students, it would be preferable to suspend further tryouts until the problems found have been resolved. If the individualization

strategy is fairly complex, it may take a larger number, up to 20 for example, before all problem areas are identified.

If available manpower permits, it is desirable to supplement the single-student tryouts with review by other instructional (or clerical) personnel for the purpose of locating grammatical and typographical errors and problems with clarity.

Selection of students to try out the CAI materials should be on a volunteer basis. Using volunteers rather than individuals ordered to the tryouts will avoid some possible attitudinal problems. Volunteers should be from the course for which the materials were developed and (usually, at least) should have completed the conventional material covering the subject matter.

The single-student tryouts should be conducted outside the classroom and should be informal. Attempting to work within the classroom is likely to disrupt regular classroom activities. Authors of the materials should be available to answer questions, provide guidance where necessary, and note areas where students have difficulty. In addition to direct observation by the author, student comments should be collected through the system's Comment facility, and student response data should be collected (these features are described in the section entitled Software Elements of the CAI Authoring System). The comments can then be reviewed and the system-provided response analysis report can be used to verify suspected problem areas. These data can then be combined with comments from subject matter specialists and others who reviewed the material to determine required revisions. Such minor revisions as correcting typographical errors or incorrect branches can be made as soon as they are identified. If major revisions are required, the revised materials must be resubmitted for subject matter specialist review and, in some cases, additional single-student tryouts would be desirable prior to formative evaluation.

Formative Evaluation. The formative evaluation component is shown in Figure 4. As opposed to the single-student tryouts, the purpose of the formative evaluation component is to evaluate the instructional effectiveness of the materials and to determine specific areas of weakness. Furthermore, the formative evaluation activities should provide an indication of how students and instructors will accept CAI as a medium in the classroom and indicate the presence of any problems in the interaction of the materials and the CBI system as a whole.

The first step in this component is implementation of the CAI module for Classroom use. This includes a number of requirements, all aimed at making the CAI materials a part of the classroom environment.

The classroom must be physically configured to accommodate CAI terminals and to handle any classroom procedures that might be uniquely required by CAI. Staff and student briefings should be held, explaining

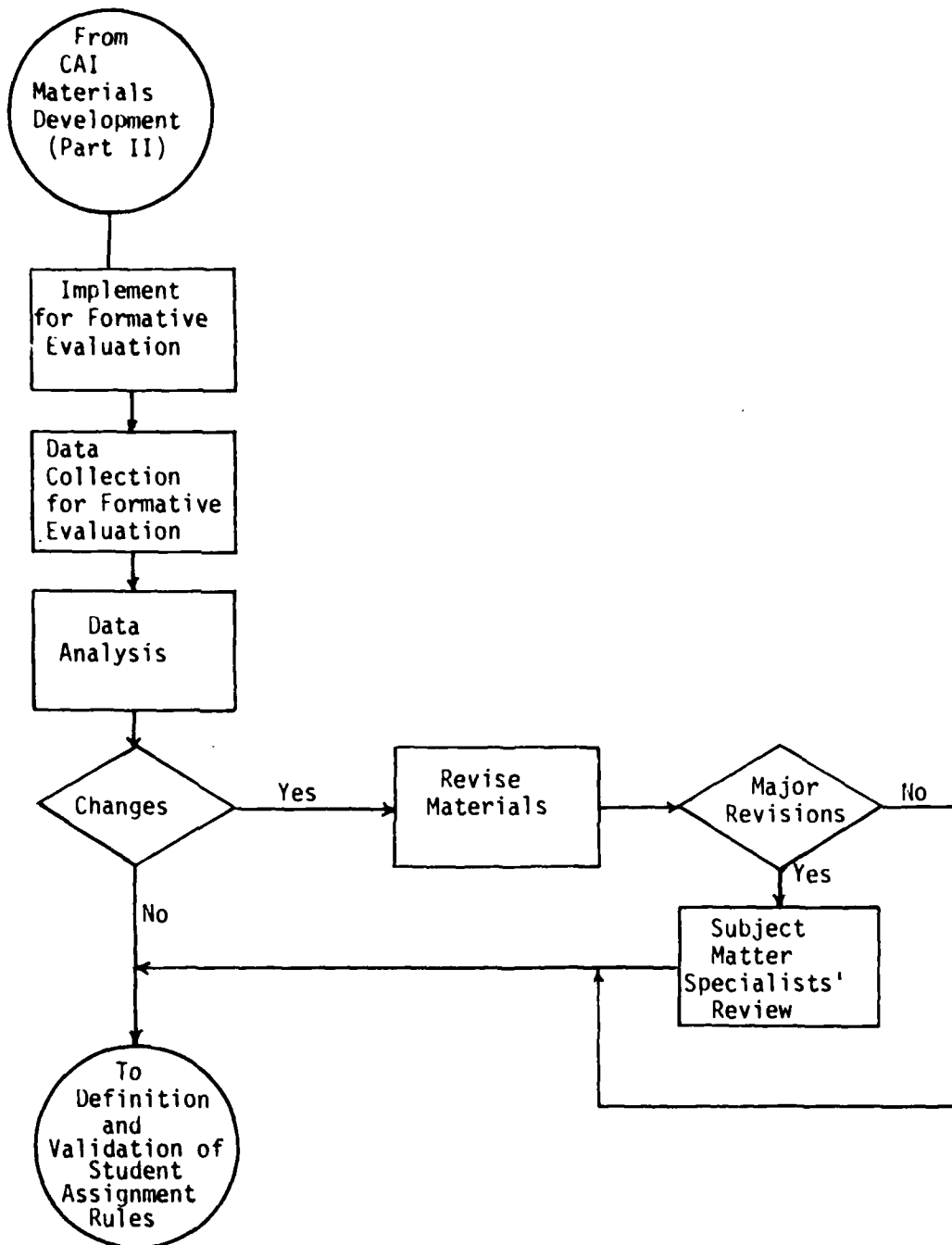


Figure 4. Formative Evaluation.

the nature and purpose of the to-be-introduced CAI. The instructors must be trained in CAI operational procedures and in counseling students on CAI lessons and use. Backup materials and procedures must be introduced, to be ready in case of computer failure. One or more members of the development team should be assigned to the classroom for the first several days to observe and assist in the transition and to answer students' and instructors' questions.

The CMI system data base records must be changed to identify the CAI terminals to the Resource Allocation Model, to reflect the addition of the CAI modules to the lesson records, and to define the rules by which CAI modules are to be assigned to individual students. Ideally, students should be assigned to the CAI module at random to provide a basis for subsequent determination of assignment rules. Typically, however, this will not result in the most efficient use of the available terminals. If there is a requirement to complete formative evaluation more quickly, an assignment rule can be defined such that a student assigned to a lesson with a CAI module will be given the CAI module if a terminal is available. This will result in maximum use of the CAI module and will speed up data collection.

The next step pertains to data collection. Data should include student performance on the CAI materials and tests (decision point data, response point data, and listing of unanticipated responses), student and instructor comments, classroom observations, and (in some cases) measures of student attitudes. In analyzing the data judicious constraints may be necessary to exclude spurious information arising from cases of mis-assignment, lesson overrides, and students' failure to follow procedures. The evaluation sample size must be agreed upon (typically 30 to 50) and target dates set for reaching milestones or terminating the formative evaluation.

The formative evaluation itself, the data analysis step, should concentrate on the standard CAI performance analysis reports (described in the next section) supplemented by classroom observation, instructor comments, and any student attitude measures. For any one CAI module, it is most efficient to begin analysis of student performance with the Decision Point Report which provides an overview of student performance within each objective, i.e., the mean number of questions presented and answered correctly, mean elapsed time to complete the objective, and the percentage of students categorized as having or not having mastered the objective. Using these data, the author/evaluator can quickly locate problem areas within the module. The Response Analysis Report (containing mean response latencies for all frames and a detailed accounting of student responses to individual questions) can then be used to more specifically determine the nature of the problems contributing to areas of instructional weakness. That is, which specific questions are being answered incorrectly by a large proportion of the students and which distractors on these questions are being incorrectly selected? Is the problem in the wording of the question itself? If not, what are

the characteristics of the preceding instruction which have led to these errors? Where constructed response questions are employed, it will be necessary to supplement the Response Analysis Report with use of the Unanticipated Response Listing.

Hopefully, major revisions to the materials will not be required following formative evaluation. Single-student tryouts should have uncovered most of the more pronounced errors and problem areas. Any major changes to tests, materials, or classroom procedures which are required should be reviewed by SMSs before the changes are implemented.

Definition and Validation of Student Assignment Rules. This component, fourth in order of the Procedural Model, is required by the assumption that it is not cost effective to assign all students to the relatively expensive CAI modules. While development costs are constant, delivery costs (i.e., terminal and central computer time) are usually sufficiently high that the CAI modules should only be assigned to those students who will benefit the most from the more interactive medium. In some cases, there may actually be a subset of students who will learn more efficiently from the original (non-CAI) materials. The steps comprising this component are illustrated in Figure 5.

To carry out this "alignment" of students with instructional media, the educational technologists must analyze the formative evaluation data for the purpose of formulating assignment rules. These rules may be either regression equations or heuristics and should be derived from information as to what type(s) of students performed best on CAI as opposed to the original materials. The performance criteria should include times to complete modules, test scores, and (if available) attitudinal scores. The rules can be derived directly from the data, or can be tempered by the introduction of factors based on experienced best guesses, and results of other CAI research. When the rules have been defined, authors of the CAI materials, SMSs, and instructors should be informed of the intent of the rules.

The assignment rules are then implemented in the data base and incorporated into classroom procedures. To provide a control group, a percentage of students (e.g., 30 to 50 percent) would continue to be assigned at random. Briefings on the rationale and expectations behind implementation should be given to instructors, staff, and students. Instructors in the classrooms affected must be trained to handle misassignments and other problems and to make assignment overrides and manual assignments. Someone must be designated to coordinate problems between the classroom and the group implementing the assignment rules, and to enforce coordination and configuration control among the various groups.

The data collected to evaluate the assignment rules would include student performance within the CAI module itself and on the lesson and block tests, times to complete the materials and tests, student and instructor comments, classroom observations, and (if available) student

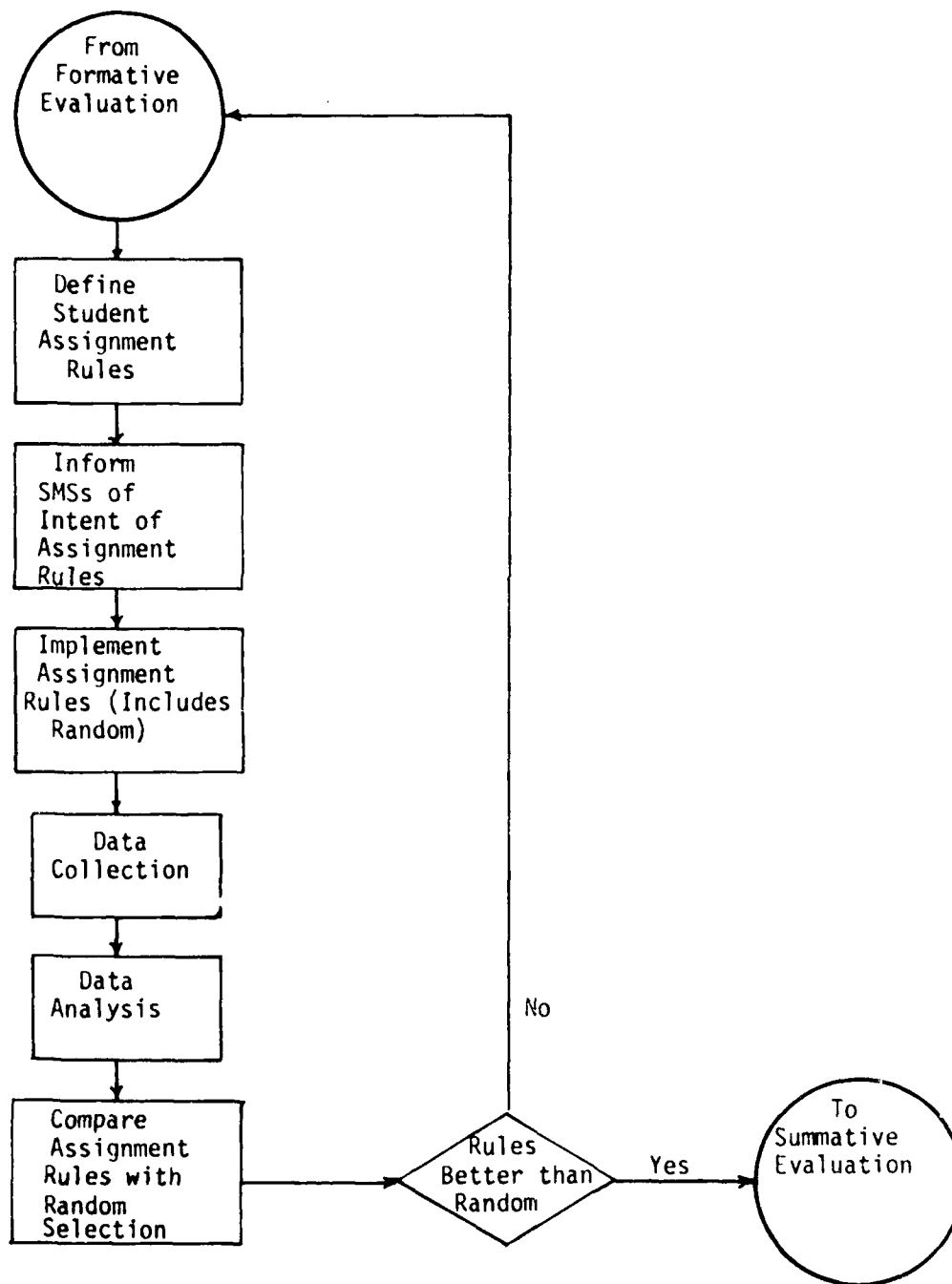


Figure 5. Definition and Validation of Student Assignment Rules.

attitude measures. There is a need to specify the hypotheses to be tested, determine data collection constraints, set time tables for data collection and the number of samples to be gathered, and determine how comments and observational data are to be used. Since the primary concern is whether the assignment rules are better than random assignment, data from both groups must be carefully compared. If random assignment proves to be as good as or better than the assignment rules, the rules definition process should be rerun. If the assignment rules are shown to be superior, implementation should continue, with periodic rechecks on effectiveness.

Summative Evaluation. Whereas formative evaluation is concerned with the instructional effectiveness of individual CAI modules and with the implementation of the materials, summative evaluation is concerned with the impact of the CAI modules and their assignment rules on the block in which they are taught and with their interaction with materials in other blocks. The steps for this component of the Procedural Model are shown in Figure 6.

Since no changes to classroom operations or the data base are required, no additional implementation procedures are necessary. Thus, the first step pertains to data collection. The principal concern is with student performance times and scores. The data of primary interest are module completion times (for both the CAI module and the original materials), lesson and block-test scores, and times and scores on lessons and blocks for which the lesson containing the CAI module is considered to be a prerequisite. Data of these types are provided by the CMI system's standard performance reports. Within-module (CAI) data collection is also continued however, to provide detailed student performance data if problems are uncovered by the more gross CMI measures. Little emphasis is placed on comments or classroom observations. Any general classroom procedural problems should have been eliminated during formative evaluation. Sample size should approximate 50 students per module.

In the second step of this component, CMI performance reports are analyzed to determine overall changes in block and course performance as a result of implementation of the CAI materials. Student performance on the CAI modules should also be re-examined for final measures that are free of the effects due to initial implementation and change, and to the novelty of CAI.

If the preceding steps of the model have been carefully followed, it is unlikely that serious problems will be detected during summative evaluation. If problems are encountered, however, they may be attributable to the module assignment rules, the instructional effectiveness of the CAI module itself, or a combination of both. If revisions to the assignment rules are necessary, the instructors should be informed of the changes made. If major revisions to the module are required, the SMSs must review the changes made. Any significant revisions of the

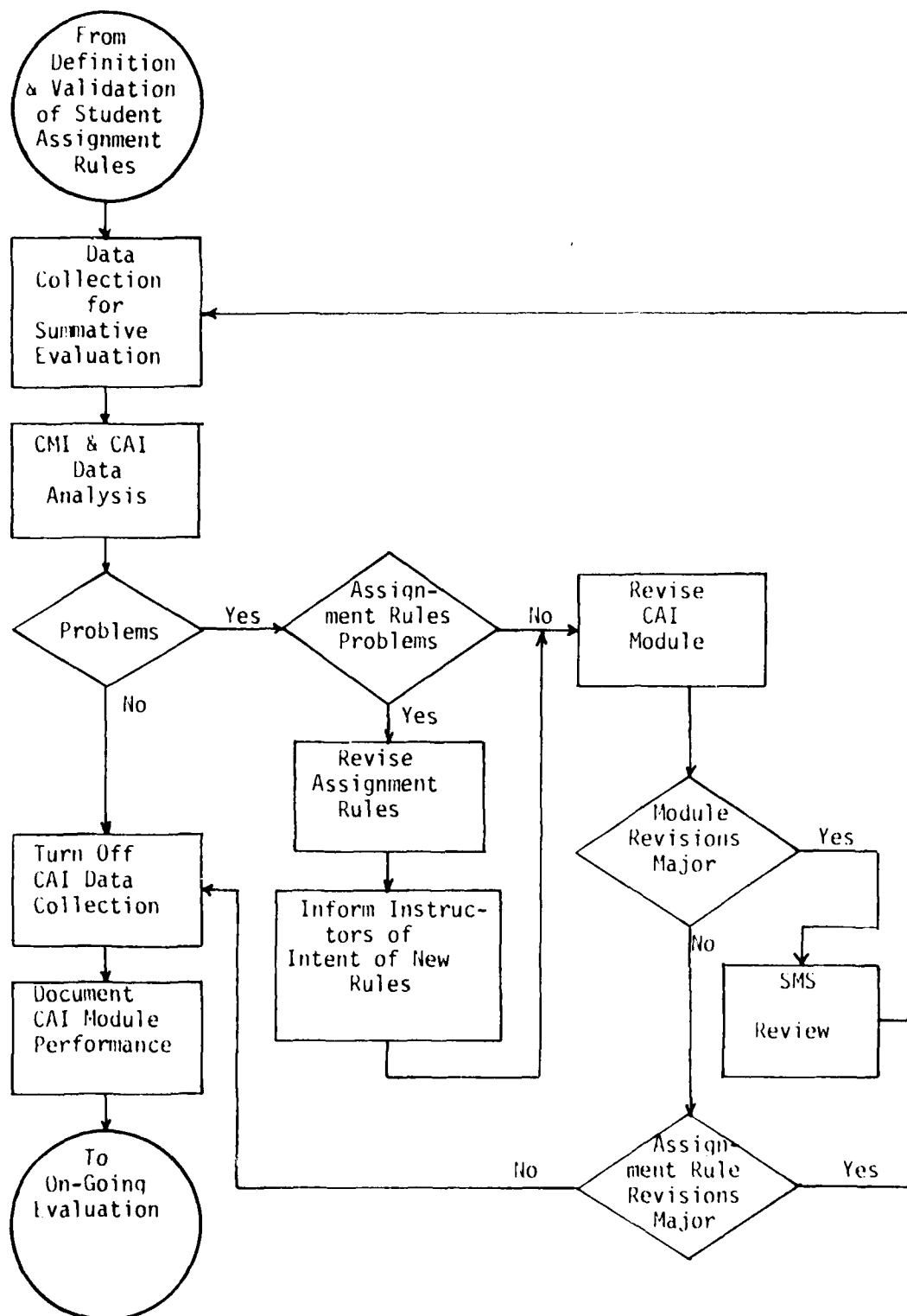


Figure 6. Summative Evaluation.

assignment rules or the module requires, at least in part, a repetition of data collection for summative evaluation.

When the authors, SMSs, and evaluation personnel are satisfied that the materials are satisfactory, the CAI data collection routines can be turned off. There is no need to continue to collect detailed performance data for CAI materials which are known to be performing well.

The last step in this component is the documentation of the CAI module's performance. This documentation provides a standard for subsequent (on-going) evaluation of the materials, tests, and assignment rules as the population or course characteristics change and provides comparison data for subsequent classes of students.

On-Going Evaluation. As the student population or course and field needs change, it may be that student performance will deteriorate. The purpose of this last component of the Procedural Model, On-Going Evaluation (see Figure 7), is to monitor student performance and to address problems which are detected by this monitoring.

The first step in this component is the periodic monitoring of student performance data collected and reported by the CMI system. The frequency of such monitoring is determined by the rate of student flow through the course and factors such as how often student or field dynamics change and whether field performance is becoming inadequate. Typically, monitoring should be conducted at least quarterly. The course's evaluation personnel are responsible for determining which data are to be examined; what constitutes a problem (e.g., is an increase of 3 percent in the failure rate for a module a problem?); and how many students must be involved before a problem is considered to be significant.

If a situation involving a CAI module is deemed to be a problem and is not readily identifiable as arising from an administrative, non-computer function, the CAI data collection routines should be re-activated. If one or more specific portions of the module are hypothesized to be the source of the problem, it may be advisable to define decision points bracketing the area.

As in formative evaluation, it would be good practice to again gather student/instructor comments and to collect at least limited classroom observations. Comments and observations may help to separate attitudinal and administrative problems from those internal to the CAI modules.

Data analysis and interpretation will eventually determine whether the problem resulted from student assignment rules, from the CAI materials, or from a non-computer administrative function. If a problem is found to be administrative, actions beyond the scope of the procedural

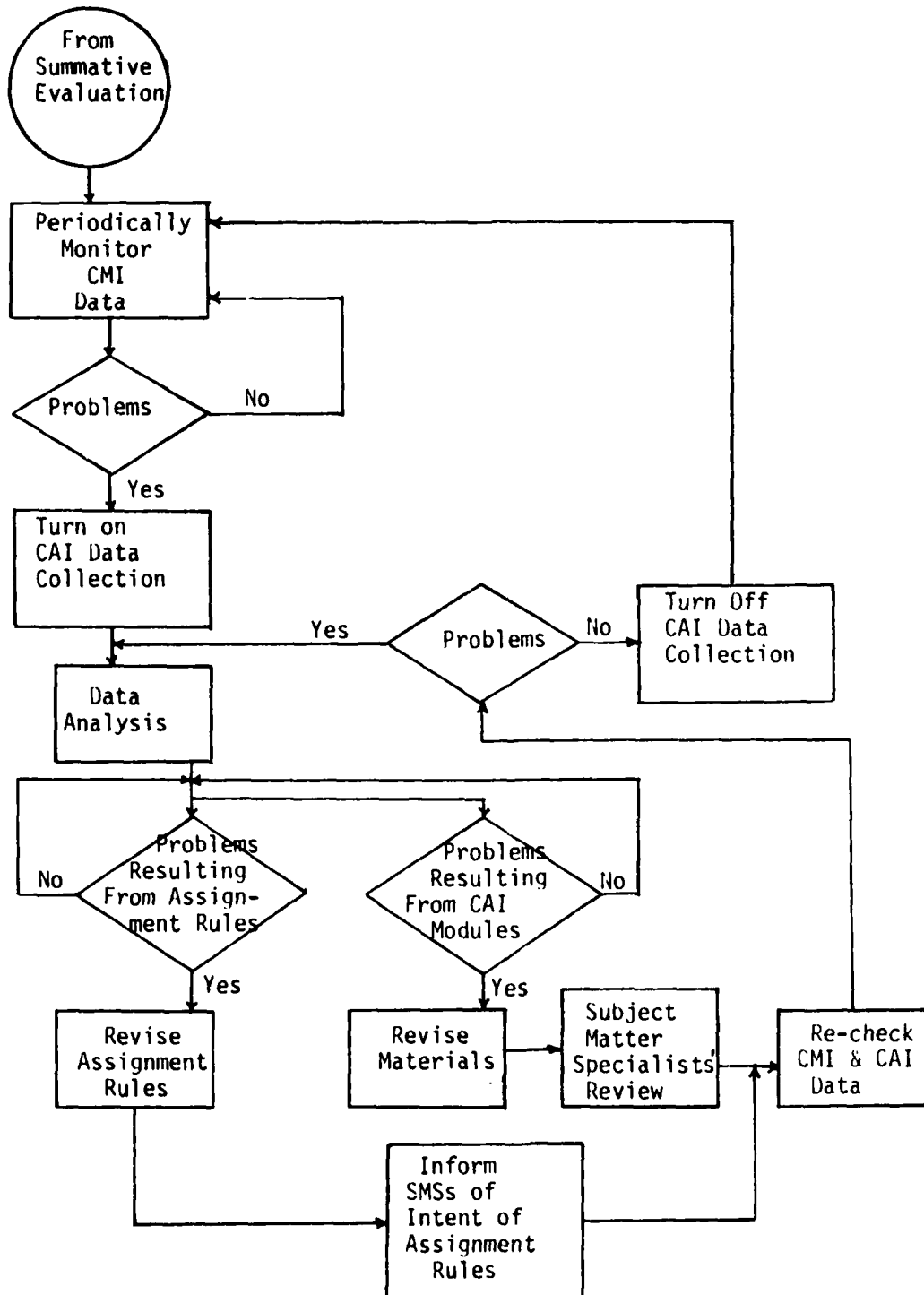


Figure 7. On-Going Evaluation.

model are required. Otherwise, revision of the assignment rules or the CAI materials is indicated.

If an assignment rule problem is identified, the steps outlined in the "Definition and Evaluation of Student Assignment Rules" component should be repeated, remembering that instructors must be informed of the instructional intent as assignment rules are revised.

If the problem is identified as being within the CAI module, the problem area(s) should be revised, following the revision steps outlined for the "Formative Evaluation" component and working with the SMSs.

In either case, revision must be followed by a recheck of the CMI and CAI data following the changes. If the problem persists, further analysis to more completely isolate the nature of the problem is required. The process essentially repeats the steps of data analysis, revision, data analysis, etc., until the problem is resolved. Once the problem has been satisfactorily corrected, the CAI data collection routines can again be turned off and periodic monitoring resumed.

Software Elements of the CAI Authoring System

The development of computer software to support efficient CAI production in the technical training environment centered around construction of a CAI Authoring Editor and a template CAI presentation program. Student performance data acquisition routines were built into the presentation program and reports were developed which focused on formative evaluation requirements. A CAI Materials Print Program was developed to provide hard copy listings of CAI materials for author and student use. All but one of the supporting programs were written in CAMIL and were designed to operate on the current AIS interactive terminals (a modification of the PLATO terminal) but provisions were made for easy transition to a less expensive terminal.

The AIS CAI Authoring System software does not require the author to also be a programmer and, due to the use of extensive author prompting, reduces the need for protracted author training. It consistently reminds the author of system capabilities which means that full exploitation of the system is more probable. It reduces program and behavioral debugging since content and strategy are treated as data. Further, it provides for meaningful student performance data collection and reporting which is both structured and flexible.

The detailed mechanics of the System's use have been reported by Montgomery and Judd (1979) and will only be summarized here. Since the time of the development work reported here, the software supporting the Authoring System has continued to evolve and expand. The software described in this section was in effect at the time of the work reported.

Authoring Editor. The heart of the software supporting the AIS CAI

authoring system is an interactive Authoring Editor--the vehicle by which the CAI author interacts with the authoring system to produce CAI modules. Rather than programming, the author defines module content and logic through an English language dialogue. Author inputs are in exactly the form which will be seen by students. As much as is possible, the Editor structures the author's task of developing module materials. At each point in the authoring process, the options available are presented in the form of a menu. Selection of a particular option typically leads to another, more specific menu of options for executing the selected action. In some cases, as in defining the overall structure of the module and in providing certain required items (e.g., a statement of the objective), the author is forced through a sequence of procedures.

The actions available to the author at each point are listed as options at the bottom of the current display. An author can select options to add, delete, copy, save, relocate, and edit materials; produce simple graphic drawings; gather student/reviewer comments; suggest student breaks; reorder or relocate material presentation sequences; define specified actions to be taken by the Presentation Program (e.g., branches and data collection); omit presentation of specified frames; and determine presentation order of response alternatives.

As structured by the Editor, a CAI module is divided into objectives which, ideally, correspond to the objectives listed by the Air Force Plan of Instruction (POI) for the lesson taught by the module. An Objective 0 (zero), containing lesson overview material, is required and the author may define up to 100 additional objectives. The authoring system is frame oriented and each objective can contain up to 100 frames, each of which may consist of up to four pages. Three classes of frame types are supported: textual content frames, question frames, and special purpose frames.

At the time of the development work reported here, six textual content frame types were recognized, each of which had a particular function: main line text presentation; elaboration; title; statement of objective; overview; and listing of any supplementary materials requirements. As was previously stated, the author entered the frame content in EXACTLY the format in which it was to be seen by the student.

Two question types were supported: multiple choice and constructed response. All formatting of question frames was done automatically. When defining a question, the author was prompted to supply the question stem, the alternatives or anticipated responses, a feedback statement for each alternative or constructed response (including the category of unanticipated responses), a prompt (or "hint") statement to be displayed after each successive incorrect attempt, and the number of attempts allowed. Definition of at least one correct answer was required. Prompt and feedback statements were optional and could be suppressed. In the case of feedback statements, the author could also elect to have a

standard feedback statement selected at random from a pool for presentation.

The special purpose frame category included two frame types - documentation and branching decision frames. Neither of these frame types was ever presented to students. Documentation frames were required during the initial creation of each objective and were intended to provide a history of the module's development, evaluation, and revision. Branching decision frames allowed an author to define a branching point without requiring that any frame material be presented.

The author was able to define three types of branching logic: logic evaluated prior to frame presentation; logic evaluated following frame completion; or, for a question frame, logic evaluated as the student responded. Pre- and After-Frame branching logic could be "unconditional" or "conditional." Unconditional branches were always executed if the student reached the branching point while conditional branches were made only if the student's actions matched conditions set by the author. Thus, the author could specify that a branch be taken conditional on (a) a specified number of an author-defined set of questions being answered correctly or (b) incorrectly, or (c) on an author-specified set of frames having been or (d) not having been presented. Response logic was only unconditional in the sense that the author-specified branch would always be taken if the student selected the specified alternative or constructed response. Any number of Pre-frame, Response Contingent and After-Frame branching instructions could be entered against a single frame. Logic statements were evaluated sequentially, both across and within categories. Thus, within each category, logic statements were evaluated in the order specified by the author until a statement was encountered for which the specified conditions were true. That branch was then taken even though the conditions specified by subsequent statements may also have been true.

Branching logic was entered in what is essentially a highly prompted, multiple choice format. The resultant instructions were then displayed in English.

Presentation Program. CAI materials developed via the Authoring Editor were delivered to students by a CAI Presentation Program. This program consisted of a general program structure and a set of support routines driven by the CAI module description, decision logic, and text records created by the Authoring Editor. Through the use of this generalized program structure and table-driven approach, a wide range of computer-assisted tutorial and drill and practice instruction could be presented with minimal programming effort.

Three variations of the presentation program were used to present (a) lessons assigned on the student's first pass through a block; (b) block review modules assigned prior to a student's first attempt on a block test, reviewing material for those objectives which the student

failed while studying the block materials; and (c) block remediation modules, assigned after a block test failure, reviewing those objectives which the student failed on the test. The basic skeletal program and support routines were written during the development of the first-pass modules and required the most extensive design and development. The programs to support block review and remediation were then constructed by slightly modifying the main loop code.

Presentation to a student began by presenting the material in Objective 0 followed by the instruction contained in the first numbered objective in the series. Frame descriptions, branching logic and text records, all created by the Authoring Editor, determined the sequence and content of the presentation. For both constructed response and multiple choice format questions, students were required to continue answering until correct, until reaching the specified maximum number of attempts, or until a particular answer resulted in a Response Contingent branch.

At any point in an objective, the student could opt to review material which had already been presented. In the review mode, text was displayed in the normal manner and questions were displayed with the student's answers indicated.

After a period of instruction and practice, an objective typically ended with a series of test questions. Given the criterion that a certain number of the questions be answered correctly, author-defined branching normally routed the student to the end of the objective as soon as the criterion had been met. If the student's performance was below criterion, the student did not normally exit the objective until troublesome points had been reviewed and retested with additional test items.

Upon exiting each objective, the Presentation Program encountered either an objective-passed or objective-failed flag set by the author. The student continued through the objectives, in sequence, until all objectives had been presented or until the program encountered a lesson-passed or lesson-failed flag. When a lesson passed/failed flag was encountered, the program generated a module test form containing a list of any objectives failed and a lesson passed or failed designator. The program then passed this form to the main AIS CMI management program, the Adaptive Model. The Adaptive Model recorded the student's performance on the lesson, generated the student's next assignment, and displayed it on the terminal. The student was then logged off.

Over the course of a long module, an author could encourage the student to take one or more breaks--to exit the module and leave the terminal for a short rest period. Module interruptions could also occur as the result of computer failure, end-of-shift, or breaks for meals. In each case, the student could log off or, if the Presentation Program did not receive a keypress for a specified period, the student was

assumed to have left the terminal. After displaying an inquiry as to whether anyone was there, the student was logged off automatically. If a module was interrupted for any reason, the Presentation Program automatically restarted the module at the frame on which the interruption occurred when the student logged back onto the terminal.

Access to the CAI Presentation Program was not limited to students. Lesson authors and reviewers could use the program to verify the module's content accuracy and to view it from the student's perspective. Author and reviewer access to the program was, however, handled by standard AIS program access methods rather than being under the control of the Adaptive Model. Having accessed a particular module, the author/reviewer could override the frame control logic and request presentation of any frame within an objective through use of a special function key. In addition, the author/reviewer could always enter comments about the material being presented. Student comments were elicited and accepted only if the Student Comment Flag had been set to "true." Completion of a module in author/reviewer mode did not result in submission of a lesson completed or failed form to the Adaptive Model. In all other respects, the user's interaction with the Presentation Program was identical to that of a student.

Data Acquisition and Reporting. To provide student performance data collection and analysis, a CAI Data Acquisition and Analysis system was developed which consisted of four major components: (a) data recording routines in the Presentation Program, (b) a Data Collection Program to move performance data from disk to tape, (c) a Data Analysis Report Program which generated three different types of reports, and (d) a Report Submittal Program to facilitate users' requests for specific reports.

Whether student performance data and comments were collected during the presentation of a CAI module was dependent on whether the author set appropriate data collection flags for that module via the Authoring Editor. This philosophy of limited data collection was adopted to avoid generation and storage of the immense amounts of data which would otherwise occur. The intent was that data be collected for formative and summative evaluation purposes, but not during normal operations except for consciously initiated sampling.

Response data represented the most detailed data category. The data were collected at the end of each frame presented to the student, regardless of frame type. In addition to identification of the student and the frame, and the time at which the frame was encountered, data collected included: (a) total time, in seconds, spent on the frame, and (b) any time, in seconds, spent in review mode if review was initiated from the frame.

If the frame was a question frame, the following data were also collected: (a) number of attempts made to answer the question, (b)

number of the alternative selected, by attempt number, (c) response latency, by attempt number, (d) number of unanticipated responses, and (e) the text of up to five unanticipated responses.

Decision Point data were collected at the end of the module, at the end of each objective, and at the end of each frame against which a Decision Point Flag had been set. In addition to assorted bookkeeping information, the following data were collected:

1. Elapsed time since the last decision point.
2. Number of questions presented since the last decision point.
3. Number of questions answered correctly since the last decision point.
4. Number of branching logic decisions processed for the current frame.

For each branching logic instruction processed, the data included (a) branching type (Pre-frame, Response and After-frame), (b) number of the instruction within its type, and (c) the branch actually taken, if any.

Four different CAI Data Analysis Reports were available to authors and evaluators: the Decision Point Data Report; the Response Analysis Report; the Unanticipated Response Report; and the Comments Listing. In addition, standard AIS CMI reports could be used to provide a description of overall module performance. All reports were requested from an interactive terminal. For the three CAI student performance reports, requests were submitted via the CAI Reports Program which prompted the user for the report request parameters, thus, the user did not need to learn how to set up job control parameters.

The Decision Point Report was generated from data, stored either on disk or tape, in the Decision Point Data File. It provided a summary of student performance within each objective and within those intra-objective segments which the author had defined by setting Decision Point flags at the beginning and end of each segment. Each component of the report contained the number and name of the Decision Point frame; whether the data reported pertained to students' first, second, or subsequent pass through that point; the elapsed time, number of questions presented and number answered correctly since the last Decision Point; the branching logic evaluated at that point; and the number and percentage of students taking each branch.

The Response Analysis Report identified the number and name of each relevant frame and whether the data reported pertained to students' first, second, etc. pass through that frame. For frames other than question frames, only time data were reported. For question frames, a matrix format was used to present student performance and response latency data as a function of the response (multiple choice alternative or constructed response) selected on successive attempts. The margins of the matrix provided a summary of student performance on the question

(total percentage correct, percentage correct by attempt and total time to correct response) while the matrix cells provided a more detailed picture of how students reacted to the question.

The Unanticipated Response Report listed each unique unanticipated response for each constructed response question. Unanticipated responses were listed in order of frequency of occurrence together with the number of times which that particular response had been entered.

Comment Listings were requested via the Print Option of the Authoring Editor (described below) rather than the CAI Reports Program. Frames against which comments had been made were indicated on the Editor's Frame List Display. The user could request that comments made on a particular frame be displayed at the terminal or that comments on one or more frames be listed on the central line printer. The comments could also be purged from the file as they were displayed or listed.

Print Program. As authors created, reviewed, and revised CAI modules, it was often useful to work from hard copy printouts of the module's content in addition to, or in place of, the displays provided by the Authoring Editor. There were also instances in which hard copy printout was desirable for student use. A feature of the CAI Authoring System was the capability to request a variety of printed listings of CAI modules' content and branching logic. The Print Program queried the author for the desired print options and then initiated a special background (non-interactive, low priority) program to produce the printouts. There were four different types of printer listings available to authors, ranging from summary information to detailed listings of frame contents. Multiple copies could be obtained of each type of listing.

At the most general level, the Module Summary Listing provided an overview of all of the CAI modules, operational or under development, currently defined in the data base. The information provided for each module included the module identifier, module title, author's ID, and the number of objectives defined within the module.

For a particular module, the Frame Summary Listing provided an overview of content of individual objectives. The information in this listing was essentially the same as the Editor's Frame List Display. Each frame in the objective was listed by number and frame name. The existence of any branching logic and Frame Flags was noted, and the maximum number of attempts allowed to answer questions was shown. If a frame was an alias (i.e., referenced another frame), the referenced frame was identified.

The most frequently used printout was probably the Frame Contents Listing, the complete printout, by frame, of all text and question material. Such a listing could be requested for an entire module, an individual objective, or a specified set of frames. The materials contained in a textual content frame, up to the full four pages were

printed on a single printer page. For a Question Frame, the printout included the question stem, the alternatives or anticipated responses with the correct answers denoted, and author-supplied feedback and prompt messages.

Finally, the Branching Logic Listing provided a hardcopy listing of all of the branching logic defined for frames within an objective. The format in which information was presented was similar to the Editor's Branching Logic displays.

In addition to the various author's listings, hard copy printout of a CAI module's content could be requested in a format appropriate for direct use by students as a programmed text. Special Purpose, Documentation, and Branching Decision frames were automatically suppressed and the author could elect to suppress any other specific frames. All other frames were printed in the order in which they occurred in the module. Branching logic was simply ignored. There are a variety of uses for such printouts. They can be used as hard copy backups for students assigned CAI modules in the case of computer failure. They are useful to instructors for answering the questions of students assigned CAI modules. Their most important function, however, may well be as a first step toward the on-line development, evaluation and revision of materials intended for off-line use.

AIS CAI Authoring Procedures Handbook

The Procedural Model for CAI development and the purpose and use of the CAI Authoring System Support software were documented in an "AIS CAI Authoring Procedures Handbook" (Lewis, 1979). The purpose of this Handbook was to provide a document that could essentially "stand alone." That is, it was intended to be an item that could be used by the average Air Training Command materials developer to learn, with no other training aids, to produce CAI materials suitable for ATC classroom use. It was to include guidance as to the characteristics that make a CAI module (or any instructional material, for that matter) a better teaching tool; describe all of the features of the CAI Authoring System and how they are used; and provide an overview of what CAI is and how it can benefit the student.

The Handbook was developed using the CAI Authoring Editor and is maintained on-line. Its contents are available in a number of formats through the Print Program. The Handbook covers all of the current functions and aspects of the Authoring System and is dynamic in nature in that revisions to the Handbook occur in near real time as modifications are made to the Authoring System. This attests to the capability of the Authoring System to provide quick turnaround for maintenance of instructional materials.

Initial review of the Handbook was conducted by contractor personnel, AFHRL representatives, and ATC administrative personnel from

the three AIS courses. Inputs from these groups were evaluated and necessary revisions made.

The Handbook was then printed and given to ATC personnel representative of the expected target population. They were asked to review the material for clarity and to make any suggestions which they thought might lead to a more understandable product. It should be pointed out that during initial review and, to some extent, the subsequent target population review, the Handbook was frequently being updated to include changes and additions to the Authoring System. Discussions about the Handbook were conducted between the contractor and the target population reviewers on a somewhat regular basis; usually once or more a week. Comments from the reviewers were generally favorable, and requests for changes were minor in nature. For the most part, their suggestions were incorporated.

IV. AUTHORING SYSTEM EVALUATION PROCEDURES

Evaluation of the Procedural Model and the Authoring System software consisted of two major components: development and implementation of CAI materials in one of the AIS courses; and training of ATC instructors in use of the Authoring System. The procedures followed in both components of the evaluation are reported here. Times required for materials development, results of summative evaluation of the materials developed, and data pertaining to author training are reported in Section V of this report.

CAI Materials Development

As outlined by the Procedural Model, the CAI development process began with selection of target content. Three types of modules were defined as a result of this component of the process--modules intended for first-pass instruction, for block review, and for block remediation. The various steps in the materials development component were followed quite closely with the exception that contractual time constraints did not permit single-student tryouts of the block review and remediation modules. Similarly, the first-pass materials were subjected to formative evaluation and revised on the basis of the evaluation results but no formative evaluation was conducted for the review or remediation modules. Due to time constraints, no attempt was made to define and evaluate student assignment rules. A partial summative evaluation was conducted for the first two module types. A dramatic reduction in block-test failures which limited the available sample size, precluded evaluation of the block remediation modules. No attempt was made to evaluate the final step of the Procedural Model--On-Going Evaluation.

Target Content Selection. It will be recalled that the first step in the Procedural Model concerns selection of the target content for which CAI materials are to be developed. Of the four available AIS courses, it was decided that the CAI authoring effort should be concentrated in the Weapons Mechanic (WM) course because that course represented an instructional setting where reasonably difficult materials are taught, there was a sizeable student throughput, student ability levels were relatively heterogeneous, and it appeared that much of the course's content would remain relatively stable for the foreseeable future. Although the course included a large number of performance tasks, students were also subject to a heavy reading load and informal observation suggested that student boredom was often a problem. An additional consideration concerned the recent results of WM field evaluation data which indicated that course graduates were not performing field tasks as well as was to be expected.

One drawback to the WM course as the CAI testbed was that in many instances, various visual aids were required to supplement the reading material on lessons prerequisite to performance tasks. At the time of this project, the Authoring System supported only a rudimentary form of computer-generated graphics. It was assumed, however, that this require-

ment could be met through the use of supplementary picture books.

Thus, the CAI to be developed would be evaluated in an area where readers may become bored with conventional texts, where textual media needed to be supplemented by visual graphics or photographs, where difficult concepts (which are often prerequisites to dangerous performance tasks) were taught to a wide variety of student abilities, and where there was an indication that current instruction was inadequate. To the extent possible, CAI development was to capitalize on the expertise of the WM subject matter experts who had helped to develop or had at least reviewed, the original materials.

The first step in selecting specific WM blocks for CAI implementation involved examining end-of-block test failure rates and completion times for each block in the course. This was done through the use of standard AIS CMI reports (the Course Evaluation Summary and Test Item Evaluation report) and special purpose data extraction using the Data Extraction Program. One of the problems noted at this time was that the content validity and reliability of many of the block tests were not as satisfactory as would be desired.

Since none of the block tests had a first attempt failure rate in excess of 15 percent at the time of the analysis, the additional criterion of anticipated content stability was coupled with block failure rate as a basis for block selection. Two blocks, comprised of materials covering guns and armaments basic to a number of aircraft, were not expected to be replaced in the near future. Since these two blocks, block 5 and 6, had relatively high failure rates of 8 and 10 percent, respectively, they were selected for the CAI development effort.

With the choice of these two blocks, lesson selection began. Only cognitive content lessons, not performance lessons, were considered. The primary lesson selection criterion was a lesson mastery test failure rate at or above 15 percent. Data for the failure rate analyses were obtained from the Course Evaluation Summary which summarizes student performance by module, lesson, and block. The calendar period from which data were drawn was 1 December 1977 to 28 February 1978. An additional criterion was that the lessons selected be typical of WM training requirements, particularly as they related to field performance.

A total of six lessons was selected, four in Block 5 and two in Block 6. Together, the lessons covered the use of technical orders, completion of forms, and general instruction on the workings of missiles, guns, rockets, and fuses. According to the course's Plan of Instruction (POI), the six lessons accounted for a total of approximately 25 classroom hours. The four Block 5 lessons and the two Block 6 lessons accounted for 44 percent and 23 percent of their respective block's total hours. There were only two other blocks in the course in which lessons with failure rates at or above 15 percent accounted for a substantial part of the block (19 percent and 29 percent). When the

lessons selected are viewed as a percentage of the blocks' cognitive content, as opposed to cognitive plus performance content, the percentage values increase to 49 and 38 percent, respectively. Thus, it could be anticipated that the CAI materials to be produced could have a substantial impact on total block performance.

Materials Development. Work within the Materials Development component of the model began with evaluation of the adequacy of the block and lesson tests and lesson content outlines. As was previously noted, problems with the adequacy of the block tests had been detected during the block selection process. A number of deficiencies were also noted in the lesson tests and content outlines. It was necessary, therefore, to expend a substantial amount of effort in revising the tests and outlines in order to provide reliable tools for evaluating the CAI materials to be produced. Such extensive revision of content and tests had not been anticipated. As revisions were made, they were submitted to WM SMSs for review and approval. In some cases, several cycles were required before agreement was reached between course and contractor personnel.

Instructional and individualization strategies were then defined for the six first-pass modules. Since these lessons had been selected on the basis of indications of lack of student mastery, emphasis was placed on achieving mastery rather than on attempting to reduce first-pass study time. Due to the specialized nature of the subject matter, few if any students would have prior knowledge of the lesson's content, so there was no apparent advantage for including pretests. In general, the instructional approach adopted within objectives was gradual presentation of the facts and concepts to be learned with heavy emphasis on embedded diagnostic questions. Students who indicated a lack of understanding through poor performance on the questions were to be routed to further elaboration of the material or, in the case of more serious problems, washed back to restudy. Where visual aids were required, supplementary picture books were to be used with specific photographs and drawings being referred to by the relevant on-line displays.

Since the content of all of the lessons was considered to be strongly hierarchical in nature, the lesson mastery tests were to be broken up into their objective-specific subscales and embedded in the CAI modules themselves. At the end of each objective, the student would be tested over the content of that objective and failure of an objective was to be treated as a lesson test failure. Under these conditions, instruction would be terminated and the student would be directed to seek assistance from his or her instructor. As strategies for specific modules were defined, they were discussed with the course subject matter specialists. No particular problems were encountered.

Somewhat different instructional and individualization strategies were defined for the block review and remediation modules which, it will

be recalled, were to be highly modified versions of the first-pass modules. The major difference was that the particular objectives to be assigned were to be selected on the basis of the student's performance on the lesson tests within the block (in the case of block review) or on the block test (in the case of block remediation). Further, the modules were to incorporate a number of pretest questions to determine specific problem areas within objectives and to branch to the relevant instruction. Short objective overviews were to replace the bulk of the "main-line" instruction contained in the first-pass objectives. The most important features of each objective were to be retained and completely new embedded questions and objective-level test questions would be required.

The next step involved the actual authoring of the six first-pass modules. Work on three of the modules began before the Authoring Editor was completed but after it had been designed and module structure defined. Therefore, this earliest authoring was done on paper display forms. When a rudimentary form of the Editor became available, materials which had been prepared on forms were input by secretaries. It was thought that some of the authors might wish to continue using forms but an additional Editor feature became available, all of the authors found it more convenient to input and format the materials themselves. All of the work on the last three lessons was accomplished in this way.

As the first-pass modules were completed, on-line and printed copies of the materials were submitted to the course SMSs for review and approval. Other than the fact that this process was relatively time consuming, relatively few problems were encountered. For the most part, suggested changes to the modules were incorporated as they were received.

Single-student tryouts were conducted in parallel with SMS review, employing off-duty student volunteers from the WM course. The tryouts were held in the contractor's on-base facility. The only serious problem encountered was the difficulty in enlisting volunteers. A computer program identified prospective volunteers from average or above average WM students. Those who chose to volunteer, were paid \$7.50 for 2 or 3 hours of their time. Either this amount of remuneration was not sufficient or payment in general may have no particular appeal; slightly less than 20 volunteers participated.

In general, the results of the tryouts were quite favorable. Some areas were found to be in need of improvement with respect to clarity and minor modifications were made on a daily basis. None of the volunteers made any adverse comments, either verbal or via the on-line Comment feature, regarding the CAI medium. All of the participants expressed a liking for CAI and thought that it would fare well in the classroom.

Since the block review and remediation modules were highly dependent on the first-pass modules, actual authoring of these modules was not begun until single student tryouts and subsequent revisions had been

completed for the first-pass modules. The four new modules, one review and one remediation module for each of the two blocks, were then developed by combining and modifying copies of the first-pass modules along the lines previously discussed. Since the first-pass modules had been developed for the most troublesome lessons in each block, it could be anticipated that on-line materials would be available for most of the objectives assigned for review or remediation. Objectives for which on-line materials were not available were simply defined within the modules with directions to the student to study these objectives off-line. As anticipated, development of these modules was found to be a relatively minor task. As the modules were completed, they were submitted to the WM SMSs for review and approval. Due to contractual time constraints and the experienced difficulty of obtaining student volunteers, the review/remediation modules were not subjected to single student tryouts.

Formative Evaluation of First-Pass Modules. While single student tryouts of the six first-pass modules were in progress, preparations were made for implementing the modules in the WM course for purposes of formative evaluation. The Block 5 and 6 instructors were briefed on the purpose and procedures of the evaluation and two interactive terminals were installed in each of the two classrooms. As revisions following single student tryouts were completed, the six modules were incrementally implemented in the classroom. Each implementation required notifying the instructor that the module would be available for assignment, providing any necessary supplementary materials, and modifying the CMI data base so as to assign the module. Because of the need to complete formative evaluation as soon as possible, the assignment rule implemented was such that a student who was eligible to study a lesson supported by a CAI module was assigned the module if a terminal was available. Two ATC instructors were on duty in each classroom throughout the evaluation period and contractor personnel visited the classrooms frequently to answer questions and help resolve operational problems.

Student performance data were retrieved and analyzed as they accumulated. During the early stages of the evaluation, only preliminary versions of the CAI reports were available. Therefore, reliance was placed on standard reports provided by the CMI system. These reports appeared to indicate that a large number of students were failing the lesson tests embedded in the CAI modules and revisions clearly appeared to be called for. Therefore, a number of modifications were made, usually involving an in-depth treatment of the more difficult concepts. These revisions did not, however, result in any substantial improvements in apparent student performance. In the absence of any clear solution, contractor personnel were stationed in the classrooms on a full-time basis to more closely observe procedures.

As a result of this more active monitoring, it was found that, in many cases, students assigned CAI modules did not read their prescriptions closely enough to note that the assignment was to a CAI module. They studied the conventional materials, took the regular off-line test,

entered the module number from their prescription on the test form (as was required), and submitted the completed test form to a management terminal. Since the number of the test form agreed with the number of the module assigned, it was accepted, and the student's performance record was flagged as being the result of the CAI treatment. In general, it tended to be the poorer students who made this type of error and it was their data which were falaciously inflating the CAI module failure rates.

Since the objective-level CAI tests did not produce a total test score while the conventional, off-line tests did, this difference was used to discriminate the data of students who had actually studied via CAI from the erroneous data. This more accurate measure indicated that the CAI modules were, with only minor exceptions, actually performing very effectively. While it would have been preferable to remove the revisions made on the basis of the falacious data and begin formative evaluation anew, such action was precluded by the limited time remaining in the contract. As a result, the CAI modules were not as "lean" as they might have been.

To avoid such problems in the future, a change was made to the CMI software such that an off-line test would not be accepted from a student who had been assigned a CAI module. In such cases, the instructor was required to override the student's assignment to the off-line module actually studied. Once the instructors were made aware of the problem, they also monitored students' assignments more closely and the incidence of students studying the wrong module decreased.

The only other major problem encountered was also operational in nature. Even when allowance was made for students failing to study the CAI modules when they were assigned, evaluation data did not accumulate as rapidly as had been anticipated. Well into the formative evaluation period, an assignment rule error was detected and corrected. While this improved the situation somewhat, a second error in the data base was later found to also be depressing the frequency of CAI assignments. This second error was not discovered until after summative evaluation had begun.

Both students and instructors expressed a liking for CAI as an instructional medium, and they made no negative comments, either verbally or via the CAI Presentation Program's Comment facility.

Summative Evaluation Procedures. Within the context of this project, the primary purpose of summative evaluation was to compare the instructional effectiveness of the CAI materials developed with that of the original materials and procedures. As was stated in the introduction to this section, the evaluation was only partial in the sense that individualized student assignment rules had not been defined and validated. Furthermore, there had not been an opportunity to submit the review and remediation modules to any type of formative evaluation.

These materials were being tried out for the first time. The evaluation criteria were also limited to the effect of the CAI modules on first-attempt study times, lesson times to criterion, lesson test performance, and performance on the end-of-block tests for the two blocks containing the CAI modules. The possible effects of the CAI on subsequent lessons and blocks were not examined.

Relatively little implementation effort was required for this phase. Instructors were briefed as to the purpose of and procedures for summative evaluation and two additional interactive terminals were installed in each of the two classrooms to facilitate data collection. Contractor personnel were not present in the classroom during summative evaluation but by then the instructors had become proficient in the CAI-related procedures and were supportive of efforts to conduct a meaningful evaluation in an operational mode.

Summative evaluation data collection was conducted in two phases. With relatively little time remaining in the contractual period, there was a danger that adequate sample sizes could not be obtained for all 10 modules. Since evaluation of the first-pass modules was considered to be of greater importance, implementation of the block review and remediation modules was postponed until samples of substantial size had been established for the first-pass modules. For the first-pass modules, the assignment rules were the same as had been employed during formative evaluation. Thus, assignment was on a quasi-random basis, i.e., CAI was assigned if a terminal was available. Overall, this resulted in approximately 25% of the assignments on relevant lessons being made to CAI modules and 75% to the original materials. In addition, it was discovered that some instructors were overriding students' assignments to CAI as they thought that the CAI treatment would be beneficial to every student. These instructor assignments were subsequently excluded during data analysis.

Once it became apparent that adequate samples would be obtained for the first-pass modules, the CMI data base was modified to assign the CAI block review and remediation modules. The same assignment rule (assign CAI if a terminal is available) was employed for the review modules. Since the CMI system did not manage block remediation, the block remediation modules were assigned manually. As the first-pass modules achieved sample sizes which were considered to be adequate, they were withdrawn to provide more terminal time for the review and remediation modules.

During the evaluation period, there were only a minimal number of block test failures. Thus, it was not possible to evaluate the effectiveness of the CAI block remediation modules.

While the CAI data collection routines were retained in an active state, all of the data required for summative evaluation were collected by the standard AIS CMI data collection programs. The data were then

retrieved for analysis via the system's Data Extraction Program (DEP). Chi Square tests of frequency data were done directly from the DEP outputs. For the analyses of variance of time data, DEP was used to create a data file which was then submitted to SPSS (Nie, Hull, Jenkins, Steinbrenner, & Bent, 1975) for analysis.

ATC Author Training

Since a major design goal of the CAI Authoring System was that ATC personnel be able to learn to use the System with very little formal training, a second aspect of the System evaluation addressed this question.

Since the ideal situation would have been for ATC personnel to learn to develop materials while continuing their normal duties, this was the first approach attempted. Copies of the Authoring Procedures Handbook were given to a number of volunteer instructors in the Weapons Mechanic, Inventory Management, and Precision Measuring Equipment courses with the understanding that they were to use it, unassisted by formal training, to develop CAI materials for use in their classrooms. They were to work on the materials whenever it would not interfere with their normal duties. All of the instructors either had a terminal in their classroom or had relatively convenient access to a terminal.

This approach was a complete failure since none of the instructors found time to develop materials within the confines of their daily duties. In some instances, they did have time to peruse the Handbook and made several worthwhile suggestions for changes.

Given that a somewhat more formal approach was apparently required, permission was sought and received from ATC for a small number of instructors to be relieved of their duties on a part-time basis to attend a semi-formal CAI development course. Three instructors, drawn from the Weapons Mechanic, Inventory Management, and Precision Measuring Equipment courses participated. None of the author trainees were computer programmers, and none had prior CAI development experience.

The training was conducted for a period of 3 to 4 hours each morning over a period of 3 weeks. During the first session, contractor personnel presented an overview of the CAI system, discussed the role of CAI within the AIS, and provided a general introduction to the Authoring Editor and the Authoring Procedures Handbook. No formal training took place during the subsequent 14 sessions. Using the Handbook as a reference manual, each of the trainees used the Authoring Editor to develop a CAI module in the area of their own specialty. Contractor personnel were available to answer questions and to review and comment on the trainees' work. On occasion, the author trainees were also able to work on their modules during the afternoons while performing their normal classroom duties.

V. EVALUATION RESULTS

The AIS CAI Authoring System was evaluated from three differing standpoints: (a) the time required for CAI materials development by contractor personnel, (b) the instructional effectiveness of the CAI modules developed by the contractor, and (c) the effectiveness of the CAI development training for ATC instructors. The results of each of these three evaluation efforts are reported in the following subsections.

CAI Materials Development Times

The one aspect of the contractor's CAI materials development effort that was more time consuming than had been anticipated concerned the work required in revising the lesson content outlines and the evaluation instruments. Since the original instructional materials and tests were available, it had been thought that this step in the procedural model would be relatively trivial. In fact, the lesson content outlines required extensive revision, and it was necessary to separate cognitive and performance elements which had been embedded in the same lessons. To assure a reasonable basis for evaluating the CAI materials, extensive revisions of the lesson and block tests were also required. In retrospect, the magnitude of the problems in this area should have been anticipated since the lessons selected for CAI development represented obvious problem areas. All other aspects of the development process were accomplished at least as quickly as had been hoped.

The contractor's CAI authoring team consisted of three members. All were experienced technical training authors of programmed text and audio-visual materials, but none had any prior CAI authoring experience. In fact, none had even used CAI as a student. None had more than minimal computer programming experience. Only one of the three could be considered a WM subject matter expert.

The team did not keep accurate records of development times but times can be estimated for the six first-pass modules. At the end of the first 6 months of the project, the first-pass modules had been revised following formative evaluation and implemented for summative evaluation. The team leader spent relatively little time actually authoring, concentrating instead on producing the Authoring Procedures Handbook, interfacing with the Authoring System software personnel, and attending to administrative problems. The other two team members were occasionally called upon for assistance on other on-going projects. A liberal estimate of the total time spent in developing, evaluating, and revising the six first-pass modules is 2200 hours. This includes the time spent in revising the block and lesson tests even though the former was not technically part of the CAI effort.

According to the course's Plan of Instruction (POI), the content taught by the CAI modules was equivalent to approximately 25 classroom hours. On this basis, CAI development required 88 work hours per POI

hour. Average student completion time, totalled across the six modules, was 18.7 hours, resulting in an estimated 118 work hours per student contact hour for first-pass modules. Development time for each contact hour of review and remediation materials amounted to approximately 15 additional hours.

The value of 118 hours per hour compares quite favorably with the contractor's experienced development times for programmed text (100 work hours per student contact hour) and audio-visual (135 work hours per contact hour) materials in the AIS environment. It also compares extremely well with other CAI authoring systems. In a study reported by Himwich (1977), it was found that military personnel working as TICCIT and PLATO programmer/authors required 246 and 222 hours of development, respectively, per each student contact hour. Since CAI development using the AIS Authoring System approaches the development time for programmed text materials and surpasses that of audio-visual materials, the effort required appears to be more comparable to conventional media development times than to the time requirements of other CAI authoring systems.

CAI Module Instructional Effectiveness

Results of the summative evaluation of the contractor-produced CAI materials will be discussed in two parts: evaluation of the six first-pass modules, and evaluation of the two block review modules.

First-Pass Module Summative Evaluation Results. Evaluation of the six CAI modules developed for first-pass study was based on comparison of these materials with the original materials with respect to five student performance criteria: (a) first-attempt lesson test failure rates, (b) objective-level failures on the first-attempt lesson tests, (c) first-attempt study times, (d) lesson times to criterion, and (e) objective-level failures on the first-attempt end-of-block tests.

For the purpose of evaluating first-attempt lesson test failures, student performance records were selected on the following basis: module assignment determined by the CMI system (i.e., at random) rather than by an instructor, all work on the module completed during normal class hours, and CMI system checks on the data indicating that they could be considered to be reliable. Performance observations were then differentiated on the basis of module number (i.e., module number 1 for the conventional materials and module number 5 for CAI).

The data resulting from these analyses are presented in Table 1. In general, averaging across the six lessons, assignment of a CAI module did result in a substantial reduction in lesson test failures, from 23% for the conventional materials to just 6% for CAI. This represents a reduction in failure rate of almost 75%. Failure rates were numerically reduced on all six lessons although the differences (as tested by Chi Square) were only significant in three of the six cases.

Table 1. First-Attempt Lesson Failure Rates as a Function of
Module Type

Block Number	Lesson Number	Conventional		CAI		Chi Square
		n	Percent Failure	n	Percent Failure	
5	2	206	19	31	06	3.11
	3	70	14	64	00	9.88 **
	4	105	25	63	02	15.68 ***
	7	191	37	30	03	13.20 ***
6	1	83	24	83	17	1.33
	6	74	19	55	09	2.43
Average Over All Lessons		23		06		

** p < .01.
*** p < .001.

It should be noted that, given the testing strategy employed in the CAI modules, there were more opportunities to fail the lesson test than was the case for the conventional modules. That is, a student assigned a CAI module was considered to have failed the lesson following the first objective failure. For the conventional modules, the student was only required to meet an overall test criterion based on the percentage of items answered correctly.

With the exception of Lesson 1 in Block 6, the CAI module failure rates were considered to be satisfactory, i.e., less than 10%. This module's 17% failure rate indicated a need for further revision.

A more detailed evaluation of lesson test performance, at the objective level, is presented in Table 2. The selection procedures employed in these analyses were the same as those used in the comparison of overall lesson failure rates. Hence, the sample sizes shown for the first objective in each lesson are the same as for Table 1. For the CAI modules, the number of observations on subsequent objectives are reduced due to students failing an objective and exiting the lesson.

As indicated in Table 2, the effect of the CAI modules was more pronounced at the objective level. Overall, averaging across the 21 objectives, assignment of a CAI module reduced the objective failure rate from 19% to only 2%, and 89% reduction in the proportion of objective failures. The CAI failure percentages were numerically less than those of the conventional modules on all 21 objectives and the differences were statistically significant in 16 of the 21 cases.

There was only one instance in which CAI failures exceeded 5% -- Objective 2 in Block 6, Lesson 1. It can be seen that the high lesson-level failure rate for this module can be attributed to a number of relatively high objective failure rates and the rule that the lesson be considered to be failed as soon as an objective was failed. On the other hand, it should also be noted that this module was found to be one of the most effective, relative to the conventional materials, in that three of the six objective failure rate differences were statistically significant at the .001 level.

It will be recalled that the major design goal of the first-pass CAI modules was to increase mastery (to reduce the number of first-attempt lesson and block test failures) rather than to reduce study time. It was still of interest to contrast the study times of the CAI modules with those of the conventional materials.

A number of additional restrictions pertaining to the reliability of the measured first-attempt study times were added to the sample selection criteria. Due to time measurement problems raised by certain classroom procedures (e.g., periods during the normal classroom day devoted to administrative work) and the CMI system's approach to resolving these problems, a relatively small proportion of the students

Table 2. First-Attempt Lesson Objective Failure Rates as a
Function of Module Type

Block Number	Lesson Number	Objective Number	Conventional		CAI		Chi Square
			n	Percent Failure	n	Percent Failure	
5	2	1	206	17	31	00	5.97 *
		2	206	23	31	03	6.40 *
		3	206	25	30	03	7.00 **
	3	1	70	03	64	00	1.86
		2	70	09	64	00	5.74 *
		3	70	10	64	00	6.75 **
	4	1	105	24	63	02	14.86 ***
		2	105	06	62	00	3.67
	7	1	191	10	30	00	3.26
		2	191	14	30	03	2.55
		3	191	33	29	00	13.40 ***
6	1	1	83	07	83	01	3.73
		2	83	47	82	07	32.73 ***
		3	83	19	76	03	10.95 ***
		4	83	22	74	04	10.50 **
		5	83	22	71	03	12.06 ***
	6	1	74	11	55	00	6.34 *
		2	74	19	55	05	5.00 *
		3	74	20	52	02	9.27 **
		4	74	20	51	02	9.07 **
		5	74	36	50	00	23.32 ***
Average Over All Objectives			19		02		

* p < .05.
 ** p < .01.
 *** p < .001.

were considered to have reliable first-attempt study times.

The results of the analyses are presented in Table 3. With only two exceptions, first-attempt study times were roughly equivalent for the two module types. For Lesson 1 in Block 6, the CAI module required only 60% of the time required by the conventional materials. For Lesson 2 in Block 5, on the other hand, the CAI module required 118% of the average time required by the conventional module. It will be recalled that the CAI modules had been revised and expanded on the basis of fallacious student performance data during formative evaluation. The Block 5, Lesson 6 module was substantially expanded at that time.

Overall, across the six modules, cumulative first-attempt study time was reduced from 1179 to 1121 minutes, a reduction of 4.9%. Although it is not possible to estimate how much less time the CAI modules might have required if unnecessary revisions had not been made, it is likely that the difference would have been substantial since relatively large amounts of elaboration were added to some of the modules.

A more pertinent time measure, which encompasses both module study time and lesson failure rate, is total time to lesson criterion. The restrictions required to assure reliable times-to-criterion were not as extensive as those required for first-attempt module times. Hence, sample sizes were not as seriously diminished. The results of the time-to-criterion analyses are presented in Table 4.

While there was only one instance in which a CAI module required significantly less time to criterion than the corresponding conventional module, the CAI module times were numerically less in five of the six cases. Overall, across the six lessons, the cumulative time required for the CAI modules was 154 minutes or 11.2% less than that required for the conventional materials.

The final evaluation criterion concerned the effect of the first-attempt CAI modules on subsequent retention as measured by objective failures on the end-of-block tests. The data selection criteria employed were the same as those used in evaluation of the lesson objective failure rates with the additional constraint that the students to be selected had not also been assigned the CAI block review module. The results of these analyses are presented in Table 5.

While the differences between the two module types were significant in only four cases, the objective failure rates for the CAI modules were numerically less than those of the conventional modules in 16 of the 21 cases. Overall, across all 21 objectives, the block test objective failure rate was only 10% for students who received CAI as opposed to 16% for students assigned the conventional materials on their first attempt on the lessons.

Table 3. First-Attempt Lesson Times as a Function of Module Type

Block Number	Lesson Number	Conventional		CAI		F
		n	Time in Minutes	n	Time in Minutes	
5	2	116	295	23	348	3.920 *
	3	63	110	59	116	< 1.0
	4	87	111	55	118	< 1.0
	7	130	167	23	158	< 1.0
6	1	16	277	48	167	19.679 ***
	6	59	219	44	214	< 1.0
Cumulative Time Across Lessons		1179		1121		

* $p \leq .05$.

*** $p \leq .001$.

Table 4. Lesson Times to Criterion as a Function of Module Type

Block Number	Lesson Number	Conventional		CAI		F
		n	Time in Minutes	n	Time in Minutes	
5	2	203	380	31	357	< 1.0
	3	70	120	64	118	< 1.0
	4	104	127	63	129	< 1.0
	7	188	199	30	165	2.492
6	1	83	301	83	224	12.632 ***
	6	74	246	54	226	1.053
Cumulative Time Across Lessons		1373		1219		

*** p < .001.

Table 5. First-Attempt Block Test Objective Failure Rates as a
Function of First-Attempt Module Type

Block Number	Lesson Number	Objective Number	Conventional		CAI		Chi Square
			n	Percent Failure	n	Percent Failure	
5	2	1	130	23	30	30	<1.0
		2	130	17	30	13	<1.0
		3	130	41	30	37	<1.0
	3	1	50	08	26	08	<1.0
		2	50	04	26	00	1.07
		3	50	02	26	00	<1.0
	4	1	86	02	18	00	<1.0
		2	86	05	18	00	<1.0
	7	1	123	01	29	00	<1.0
		2	123	25	29	17	<1.0
		3	123	18	29	28	1.39
6	1	1	77	23	45	09	4.03 *
		2	77	31	45	11	6.31 *
		3	77	40	45	24	3.15
		4	77	23	45	07	5.57 *
		5	77	00	45	02	1.73
	6	1	58	03	33	06	<1.0
		2	58	07	33	03	<1.0
		3	58	17	33	09	1.14
		4	58	12	33	09	<1.0
		5	58	24	33	06	4.74 *
Average Over All Objectives			16		10		

* $p < .05$.

To summarize, in comparison to the conventional materials, the six first-pass modules produced via the CAI Authoring System (a) reduced average lesson failure rates from 23% to 6%, (b) reduced average lesson objective failure rates from 19% to 2%, (c) reduced cumulative first-attempt study time by 4.9%, (d) reduced cumulative lesson time to criterion by 11.2%, and (e) reduced the average end-of-block test objective failure rate from 16% to 10%.

Review Module Summative Evaluation Results. Due to their nature, summative evaluation of the two block review modules was less extensive than was the case for the six first-pass modules. Block test objective failure rates were examined as a function of review module type. The data selection criteria employed were that the student was assigned the particular module at random by the CMI system, that no part of the review lesson was completed as homework, that the data were considered reliable by the system, and that the student had failed the objective in question during his or her first-pass study in the block. This latter criterion was the basis on which objectives were recommended for study under the conventional block review procedures and presented for study within the CAI review modules. The results of the analyses are presented in Table 6.

Since only data from those students who had failed the objective in question during their first-pass study were considered, the sample sizes for each objective were quite small. None of the Chi Square tests made were significant. In fact, only three of the Chi Square values exceeded 1.0. The results were still considered to be encouraging, however, since over the total of 492 observations for the conventional review procedures and 153 observations for CAI, the average objective failure rate was reduced from 15% to 11% by assignment of CAI review.

ATC Author Training

It will be recalled that the first approach to training ATC personnel in CAI development attempted to have instructors learn to use the Authoring System while continuing their normal classroom duties. This was not at all successful; none of the instructors found time for the extra work.

As a means of providing the author trainees with time for CAI development work, the second approach to training employed a training course which, although informal, did have a scheduled meeting time. Three ATC instructors, one from each of three courses supported by the AIS, came to the contractor's facility for 3 to 4 hours each morning, 5 days a week for 3 weeks. No formal training took place after the first session but contractor personnel were available to answer questions and to review and comment on the trainees' work. On occasion, the trainees were able to continue their CAI authoring work during their normal afternoon classroom duties.

Table 6. First-Attempt Block Test Objective Failure Rates as a Function of Review Module Type

Block Number	Objective ^a Number	Conventional		CAI		Chi Square
		n	Percent Failure	n	Percent Failure	
5	2-1	21	10	12	00	1.22
	2-2	35	14	14	14	<1.0
	2-3	38	34	13	31	<1.0
	3-1	6	17	3	00	<1.0
	3-2	10	00	6	17	1.78
	3-3	12	08	5	00	<1.0
	4-1	38	03	8	00	<1.0
	4-2	15	00	3	00	0.0
	7-1	13	00	7	00	0.0
	7-2	16	37	13	23	<1.0
	7-3	48	25	19	16	<1.0
6	1-1	4	24	2	50	<1.0
	1-2	41	37	5	40	<1.0
	1-3	22	45	4	25	<1.0
	1-4	25	12	6	00	<1.0
	1-5	24	00	8	00	0.0
	6-1	13	00	2	00	0.0
	6-2	17	12	6	00	<1.0
	6-3	24	04	5	00	<1.0
	6-4	24	21	5	00	1.26
	6-5	46	17	7	14	<1.0
Average Over All objectives		15		11		

^a Corresponds to Lesson Number-Objective Number as taught in the block.

At the end of the 3-week period, each author trainee had developed a module, had it reviewed by the contractor and other ATC personnel, had run limited single-student tryouts, and had made minor revisions on the basis of these reviews and tryouts. Due to the time lost during the first, unsuccessful training attempt, the training came too late in the contract period to allow for material implementation and evaluation in the classrooms. One of the modules was implemented briefly in the WM course but no data were collected since a course reorganization which occurred shortly thereafter eliminated the lesson. From what is known through observation and verbal comments, the module fared well during its short period of use.

In the opinion of the contractor personnel monitoring the training, the author trainees became reasonably proficient at using the Authoring Editor. The trainees asked relatively few questions after the first few sessions. Most of the suggestions made by contractor personnel pertained to the need for more frequent questions in the modules and increased individualization through branching. The three modules developed all contained branching logic, feedback, prompts, and some simple graphics. The consensus of those reviewing the modules was that they were of good quality and had capitalized well on the capabilities of CAI. In general, this learning was accomplished almost solely through use of the Handbook and the guidance provided by the Editor itself. A very small portion of the training time was taken up by the trainees seeking assistance or being given guidance.

The comments of the author trainees were all favorable and their enthusiasm for the project was very high. All of the trainees expressed an interest in having CAI implemented in their respective courses.

The time needed to train the ATC instructors to use the AIS CAI Authoring System was roughly equivalent to 8 full days. This compares very well with Himwich's (1977) report of 7 weeks of familiarization and 3 weeks of training for TICCIT authors, and 2 weeks of training and subsequent consulting support from PLATO project personnel for PLATO authors.

The author trainees kept records of the time spent in module development. On the average, the time required to produce a module ready for formative evaluation was 90 hours per student contact hour. While additional time would have been required for formative evaluation and revision, it appears that the total time would have approximated the estimated development times of contractor personnel.

VI. CONCLUSIONS AND RECOMMENDATIONS

The authoring system approach described here appears promising. Experience to date has demonstrated that reasonably effective CAI can be produced at a very acceptable cost in terms of work-hours per student contact hour and that ATC personnel can learn to use the system in a reasonable period of time without formal training. As it stands, the authoring system is ready for use by ATC instructional development and evaluation personnel. This final section summarizes the observed strengths and weaknesses of the authoring system, suggests specific areas for further development, and outlines a number of recommendations for system utilization.

Effectiveness of the Authoring System and Suggestions for Further Development

On the basis of the performance results discussed in the preceding section of this report, it can be concluded that the CAI materials produced under this effort were reasonably effective; substantially more than the lesson materials which they replaced. Assignment of the six first-pass modules resulted in dramatic reductions in objective failure rates on the lesson tests and substantive, although not as striking, improvements in retention as measured by objective failures on the end-of-block tests.

It must be admitted that, in terms of one of the more central measures of success, total time to criterion, the 11.2% reduction demonstrated is not as dramatic as might have been hoped for. These savings, however, must also be evaluated in the light of the CAI materials development effort required. It will be recalled that, on the average, the six first-pass modules required only 118 work hours of development time per student contact hour, a labor requirement which is comparable to production of conventional programmed text and audio/visual materials and much less than the typical time requirements of CAI development with conventional CAI authoring systems. From this standpoint, the product of the CAI authoring system reported here appears to be extremely cost effective.

Each of the three major components of the system, the procedural model, the support software, and the Authoring Handbook will now be examined and discussed in some detail.

Procedural Model. Overall, the evaluation results appear to support the developmental approach outlined by the procedural model for the particular application for which it was designed. While problems were encountered in two areas, they were more of the nature of management problems rather than problems with the model per se.

First, insufficient effort was originally scheduled for the tasks of evaluating and revising the criterion measurement instruments and the content outlines for the lessons selected for CAI development.

Given that these lessons represented known problem areas, planning for materials development should have made greater allowance for at least a portion of these problems deriving from inadequacies of content definition and inaccuracies in the criterion tests.

The second problem area concerned inadequate emphasis being placed on close supervision of procedures during formative and summative evaluation. This was found to be particularly critical when the CAI medium itself was being introduced into a course for the first time. During the evaluation effort, problems resulting from a lack of closer supervision arose in both classroom operations and in definition of management rules in the data base.

During formative evaluation, the problem of student performance data becoming contaminated by the data of students who were assigned but did not study the CAI modules could have been avoided if more complete checks had been provided by the CMI system. Past experience with the operational AIS, however, has shown that it is next to impossible to anticipate the variety of ways in which assumed procedures will be violated, whether intentionally or inadvertently. A more practical solution to problems of this type is to provide much closer supervision of classroom procedures, at least during the initial stages of implementation.

Another problem in this area concerned errors in the module assignment logic. While the AIS assignment rules are not unduly complex, they were designed to allow for a wide variety of approaches to assignment decisions. Since this was the first instance in which CAI had been implemented in one of the AIS courses on any major scale, more emphasis should have been placed on assuring that the assignment rules were operating in the manner intended.

If there was any one aspect of the model which was found to be particularly helpful, it was the emphasis on constant communication among the materials authors, the course's subject matter experts, and the instructors. While this communication was expensive in terms of both work-hours and elapsed time, it was shown to be well worth the effort. Although there were occasional problems resulting from communication failures, materials review, implementation, and changes to classroom procedures, all proceeded much more smoothly than had been the case for several similar prior experiments. At the conclusion of the evaluation period, the course personnel who had been involved remained strongly supportive of CAI in general and of this specific project in particular.

There is no doubt that the procedural model can be, and hopefully will be, further refined through subsequent CAI development experience with the AIS authoring system.

Authoring System Support Software. In assessing the various software features and components of the CAI authoring system, the major con-

tributor to simplifying the task and hence reducing costs is probably elimination of any need for the author to work in a computer language. All of the programming work has been done beforehand and provided in the form of the Editor and Presentation Programs. Further needs for programming effort will depend on how adequately this software meets the requirements of future applications. Due to its flexibility, it is anticipated that the existing software could serve the needs of the AIS environment for some time to come. Eventually, however, developing author expertise should justify increased software capability.

The second greatest factor in facilitating the author's task is probably the extent to which that task is structured by the Editor. The overall structure of the module is determined for the author, units within this structure are matched to the requirements of the environment, and the occurrence of critical units is either forced or prompted. While the author retains a great deal of flexibility, this flexibility is exercised through selection of specific options which provide a degree of control over the authoring process, while reminding the author of the various courses of action which may be taken.

A third major factor in facilitating authoring is undoubtedly the human-engineered, computer-aided input, formatting, and editing capability provided by the Editor. Other than the approach to defining branching logic, there is little here that is novel, only the application of existing technology to a particular problem area. Given the diminishing cost of computer use, there is little reason not to provide authors with the benefits of this technology.

It is difficult, at this time, to evaluate the utility of the automatic, structured student performance data collection and analysis routines. The capability provided appeared to be adequate for formative evaluation of the six first-pass modules but more extensive prompting and guidance in the use of the data collection routines and interpretation of the reports might be desirable.

There are certainly recognized inadequacies in the authoring system software, primarily in the areas of constructed response recognition and author-generated graphics. It would be desirable to develop a dialog within the Editor which would guide the author through the steps of defining more sophisticated rules by which anticipated responses to constructed response questions are to be judged. It is also suggested that a graphics editor be developed which would allow the non-programming author to generate drawings either by defining basic geometric elements (e.g., straight lines, circles, arcs) or through the use of a light pen or digitizing device. Initial work in both of these areas has, in fact, already begun.

In a totally different area, it is suggested that the utility of the authoring system could be substantially increased through provision of additional software tools for managing the authoring process. The

approach envisioned includes capturing relevant parameters of the development process, such as development status and rate of completion, and providing managers with access to this information through summary displays and reports.

Authoring Procedures Handbook. On the basis of the success of the limited author training for ATC personnel, it is tentatively concluded that the AIS CAI Authoring Procedures Handbook did meet its goal of providing a document which could be used by the average ATC materials developer to learn to produce CAI materials without further formal training. As is the case for the other components of the authoring system, however, there is certainly still room for improvement. In particular, the Handbook would benefit from increased emphasis on the concepts of individualization and the formative evaluation/revision process. More concrete examples of problems and problem solving procedures in these areas would also be quite useful.

Given that the Handbook content is available on-line, an obvious step for further development would be to generate a version of the Handbook which is more interactive; a self-instructional program containing more practice examples and criterion tests. Further, the Handbook's utility as a reference manual could be increased substantially through a system of cross referencing to specific problem areas. Initial steps in this direction have already been taken.

Recommendations for CAI System Utilization

The major conclusions drawn from this study pertain to the finding that CAI materials can be developed at a reasonable cost rather than to the effectiveness of the CAI medium per se. Thus, the intent of the recommendations outlined below is to suggest potential benefits to be derived from broader application of an instructional technology which has already been shown to be effective in a variety of contexts.

An obvious next step would involve further development and implementation of CAI modules in the courses supported by the AIS. While it is suggested that specific lessons be selected on the basis of the procedures outlined in the Procedural Model, there are some areas of instruction in the current AIS courses which appear particularly promising. These include remedial mathematics review and drill and practice in the Precision Measuring Equipment course, troubleshooting concepts in Precision Measuring Equipment and the Weapons Mechanic course, and a variety of procedural tasks in the Inventory Management course.

With some modification to the presentation program, the AIS CAI capability could be extended to resident training courses which are not currently supported by the AIS. For example, there are a number of promising applications in courses taught by Lowry's Armed Forces Air Intelligence Training Center.

Eventually, one of the most promising areas for low cost CAI would appear to be in detached or on-the-job training. Given the availability of terminals located on operational command bases, CAI would provide a means by which development and maintenance of instructional materials could be centralized and new and revised materials could be rapidly disseminated to the field. Once such an instructional distribution system was in place, it could also be beneficially employed in related areas. For example, technical orders and other forms of documentation maintained on-line could be quickly updated at a central location and dispatched immediately to all applicable sites.

One aspect of the AIS CAI authoring system which was addressed only scantily by this study is the availability of printed copies of CAI modules. An obvious application for such materials is as backups for CAI modules, to be used in case of computer failure or an inadequate number of terminals. In addition, however, there would appear to be several advantages to on-line development of materials intended only for off-line use. Initial development would benefit from the structure and guidance provided by the Editor as well as its text formatting and editing capabilities. Printed copies could be produced as required for peer review or, where terminals were available, review could be on-line; in which case the system's Comment facility would be available. Revisions found to be desirable during formative evaluation could be made immediately and relevant portions of the text reprinted for use the next day. Alternatively, formative evaluation itself could be conducted on-line, providing more detailed student performance data than would otherwise be available. Once the materials have been approved for final implementation, a copy could be printed for reproduction or, if only a small number of copies are required, reproduction could be bypassed by printing multiple copies. If the materials are then archived and stored on tape, they could readily be retrieved, revised, and reprinted when subsequent revisions were found to be necessary.

Any further implementation of the AIS CAI authoring system is largely dependent on provision of opportunities for author training. In congruence with the intent of this project, the amount of formal training required has been substantially reduced but, as was discussed, the anticipation that training could take place on-the-job was apparently unrealistic. At a minimum, it appears necessary to provide a designated meeting time and place for the CAI author training "course." Ideally, author training could be provided as part of the normal ATC Instructor Training Course.

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APPENDIX A

GLOSSARY OF AIS TERMS

ADAPTIVE MODEL - A set of computer programs that generate individual instructional assignments, predict and assign individual block and course completion time targets (Student Progress Management), allocate training resources, and are the vehicle for accomplishing continual evaluation and refinement of courseware.

ADVANCED INSTRUCTIONAL SYSTEM (AIS) - A prototype, comprehensive computer-managed and computer-assisted instructional system to provide the following automated capabilities in support of large scale training: individual instructional assignments, student progress management, resource allocation and scheduling, information storage and report generation, evaluation, and research control.

ALTERNATIVE MODULES - Modules utilizing different instructional approaches from previously existing modules to meet the specific needs of particular types of students and/or certain course requirements. (See Instructional Module).

BLOCK - A course component comprised of lessons and modules that cover a specific subject/content area and normally ends with a comprehensive test.

COMPUTER-ASSISTED INSTRUCTION (CAI) - An instructional mode which provides instruction via an interactive computer terminal. Tutorial instruction, drill and practice, and/or simulation take place at the terminal and other instructional media may be integrated with the terminal display. Utilization ratio is one student per interactive terminal.

COMPUTER-BASED - CAI and/or CMI support of instructional programs.

COMPUTER HARDWARE - The hardware components that comprise the computer system and include the central processor; various types of memory units; printout unit; and control, display, and distribution units.

COMPUTER-MANAGED INSTRUCTION (CMI) - Use of the computer to manage students through the instructional process. The computer's role is that of a diagnostician and manager of instructional events. Through the Adaptive Model, the AIS generates individual instructional assignments, predicts and assigns individual block and course completion times, allocates training resources, and evaluates tests and courseware. The utilization ratio (in the case of the AIS) is 100 students per management terminal.

GLOSSARY OF TERMS (Continued)

- COMPUTER SOFTWARE - A logical grouping of programmed computer codes that give commands to a computer to perform a particular function. A unique AIS software component is the Computer Assisted/Managed Instructional Language (CAMIL) that facilitates development and delivery of both CAI and CMI.
- COURSE - A block or a series of blocks of instruction designed to satisfy Specialty Training Standards for a particular Air Force Specialty Code and skill level. Formal, resident training conducted at an Air Training Command installation.
- COURSE DATA BASE - A collection of computer files containing the parameters and flags which control the operation of the Adaptive Model for a specific course.
- COURSE EVALUATION SUMMARY (CES) - A computer-generated report of student performance data (e.g., average completion times, scores, and failure rates) available for one, selected combinations, or all lessons and/or blocks of a specific course. The CES summarizes student performance at the module, lesson, and block level.
- COURSEWARE - Generic term for all AIS instructional material.
- HEURISTIC MODELS - Logical "If...then" statements used to assign students to alternative modules. These logical statements can be based solely on expert judgement, on previously collected and analyzed data, or on a combination of both.
- INSTRUCTIONAL MATERIALS - Printed, audio, visual, or electronically displayed information used in instruction. Includes programmed texts, picture books, workbooks, audio/visuals, checklists, technical orders, CAI presentations, and tests.
- INSTRUCTIONAL MODULE - A specific package of instructional materials and related training resources for presentation of a specific AIS lesson. A lesson may have more than one instructional module. All modules for a lesson teach the same objectives but differ in the method of presentation and/or strategies used.
- INTERACTIVE (A) TERMINAL - Consists of a plasma display and keyboard and is used by instructors and course authors to interact with the AIS central computer and data files and by students for on-line, adaptive testing and CAI.
- LESSON - The smallest testable unit of instruction within a block of instruction: Supported by one or more specific instructional modules to enable achievement of a learning objective or series of objectives.

GLOSSARY OF TERMS (Continued)

MODULE - See Instructional Module.

PREASSESSMENT BATTERY - A collection of tests given to students before they begin a course. The battery is designed to measure student abilities, attitudes, interests, and backgrounds. Preassessment data, in conjunction with Within-Course Testing, are used for individualized instructional assignment and Student Progress Management.

PRESCRIPTION - A computer-generated student status report indicating (a) the student's performance on the previous assignment, (b) the next assignment, and (c) any training resources required for this assignment.

RANDOM ASSIGNMENT - The option to specify a percentage of students who should be randomly assigned to the alternative modules for a lesson. Provides control groups for AIS-related research and for development of regression equations.

REGRESSION EQUATION - Statistical methodology employed in calculating regression models. The mathematical equation which provides the best prediction (least squares fit) of expected student performance. Regression equations are based on the performance of prior groups of students.

RESOURCE ALLOCATION - A function of the Adaptive Model for managing all training resources declared in the Course Data Base as computer-managed. The AIS capability to balance student flow through a lesson group, block, or course to avoid queueing as a result of resource unavailability and to maximize use of critical resources.

SELF-PACED CMI COURSE - A self-paced course supported by, as a minimum, baseline CMI.

SELF-PACING - A generic description of instructional programs in which learning and progress occur at each student's self-established pace.

SOFTWARE - See Computer Software.

SPECIALTY TRAINING STANDARD (STS) - Air Force established standards that specify knowledge and skill requirements for training in Air Force Specialty Codes and are the primary control documents for type III (formal/resident) courses.

STATE-OF-THE-ART - Current level, state, or condition of technology in disciplines related to computer-based education and training.

GLOSSARY OF TERMS (Continued)

STATISTICAL SIGNIFICANCE - The probability that the observed difference between two or more groups could have occurred by chance alone.

STRATEGIES - Specific instructional techniques applied within a module, lesson, block, or other sequence of instruction which, considering the particular learning objective(s), are designed to meet the individual needs and characteristics of various types of students.